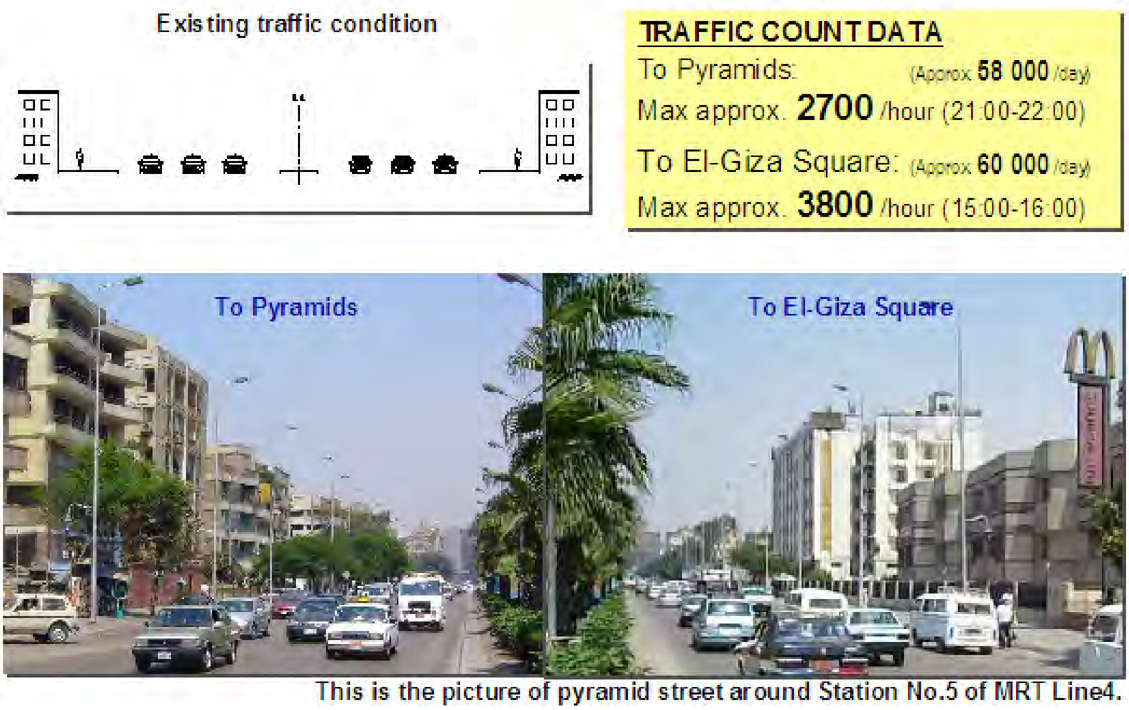
4.7.5 Planning of Construction Method

(1) Typical Consideration

Construction of the station will be located in Pyramid Street which is subject to heavy traffic. According to the traffic count data, the traffic volume is approximately 2700 - 3800 cars per hour as shown in Figure 4-188.



Source: JICA Study Team

Figure 4-188 Existing Traffic Condition

In the past construction of the metro station in Egypt, the roads where the stations are situated have been blocked and diversion routes were provided.

On the other hand, the road is not completely blocked if road decking method is applied as adopted in many countries including Japan. This is intended to avoid deterioration of the road service level.

Comparison between the present condition in Egypt and Japan traffic condition during construction is shown in Figure 4-189, and comparison of total cost is shown in Table 4-69.

If traffic will be blocked during the construction which is usually implemented in Egypt, a serious traffic congestion as well as social and economic loss will occurr.

Therefore, the construction method should be planned to avoid the blockage of the road as much as possible.

Source: JICA Study Team

Figure 4-189 Comparison of Traffic Condition During Construction

Table 4-69 Comparison of Total Cost

Unit: million USD

Item		Non traffic blocked (Minimum 4 lane)	Traffic blocked (Minimum 1 lane)
Increase construction cost	Road decking cost	2.7	0.0
	Cost of Schdule extention	0.8 (applox. 4 month)	0.0
Cost of social economical loss		0.5	5.0 ～ 25.0 ※
Total cast		4.0	5.0 ～ 25.0

Note)
Above cost is a rough estimate per one station.
※ The cost of social economical loss depend on Gross Domestic Product (GDP).
Minimum cost, 5 million USD, based on average GDP per one person.
Maxmum cost, 25 million USD, based on 5 times of average GDP per one person.

Source: JICA Study Team

(2) Construction Method

The arrangement of station for Metro Line 4 Phase 1 is shown in Figure 4-190. Respective construction method is classified into three types as follows:

- Typical construction method on Pyramids Road: Sta.No.5 - Sta.No.11
- Special construction method on hard point: Sta.No.1 - Sta.No.4
- Special construction method: Sta.No12 – Sta.No.15

Most stations can be constructed by typical construction method.

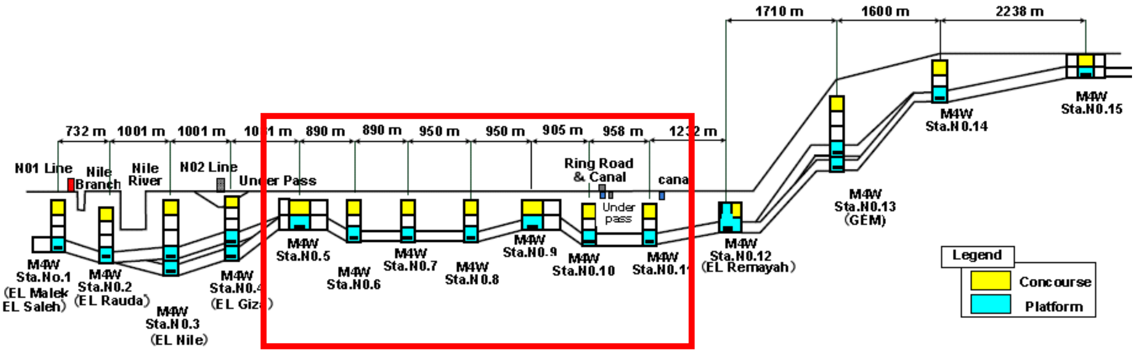
a) Study on typical construction method on Pyramids Street

i) Location and Consideration

Considerations for typical construction method of stations are as follows

- \- Construction on Pyramids Road.
- \- Cut-and-cover method with diaphragm wall and road decking.
- \- Number of underground floor is two or three.
- \- Construction is below ground water.

The location of stations constructed through typical construction method is shown in Figure 4-190.

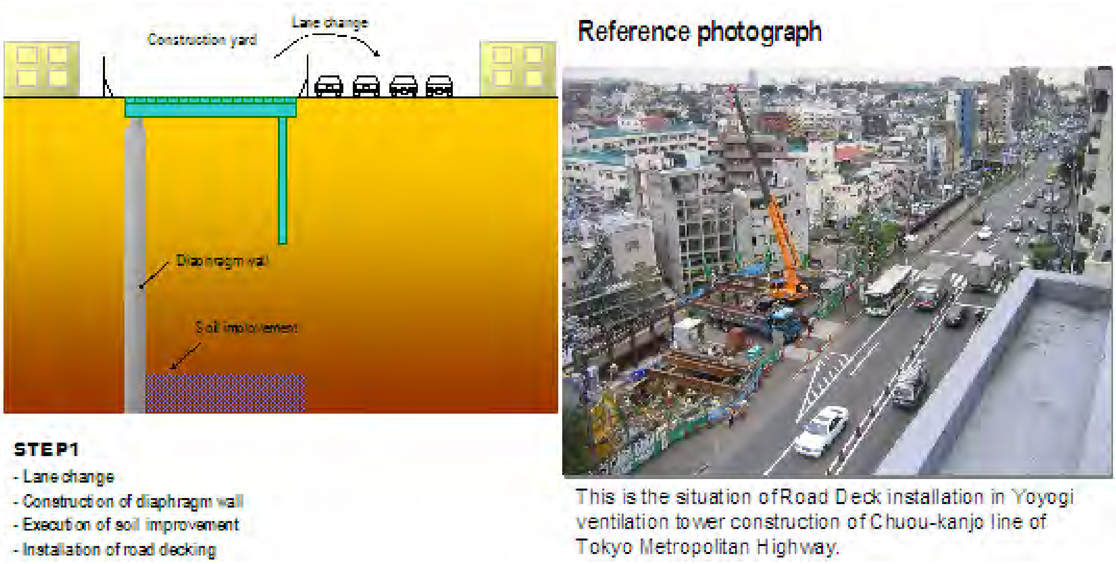


Source: JICA Study Team

Figure 4-190 Location of Stations Constructed Through Typical Method

ii) Study on the Procedure for Construction

Procedure for construction is shown in Figure 4-191 to Figure 4-200.



Source: JICA Study Team

Figure 4-191 Construction Procedure (1) of Typical Method

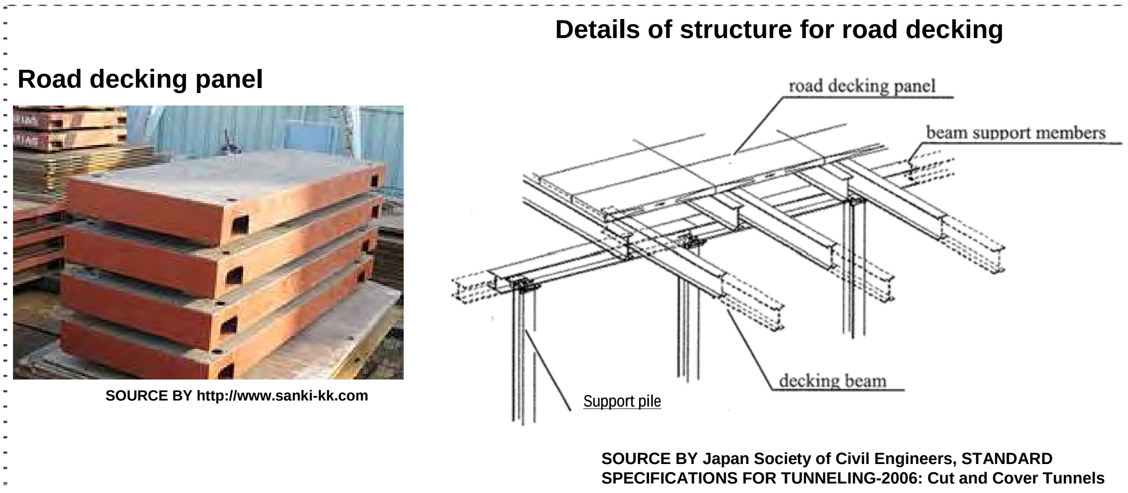
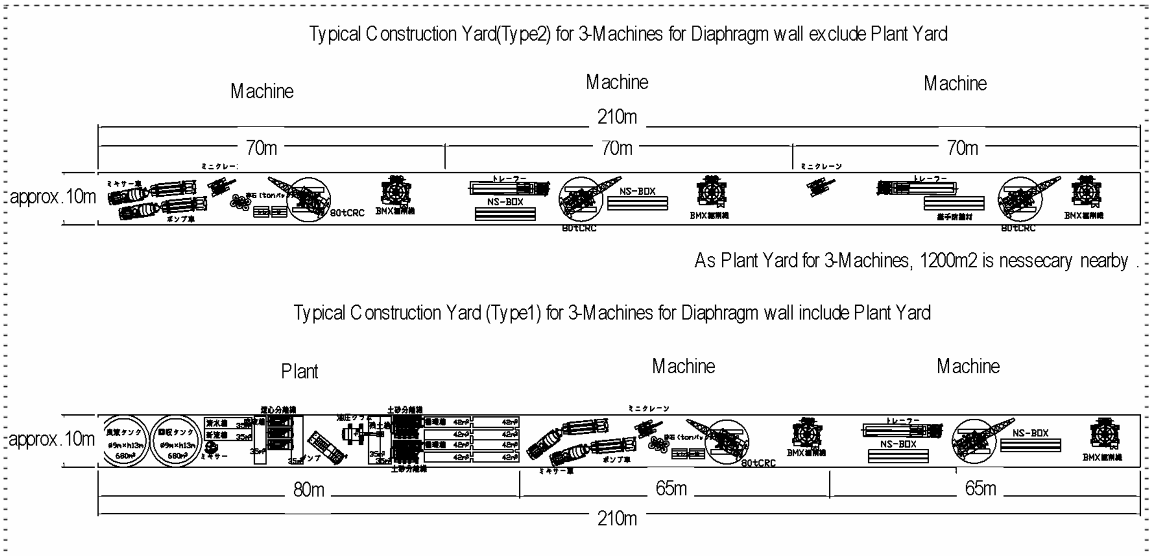


Figure 4-192 Road Decking

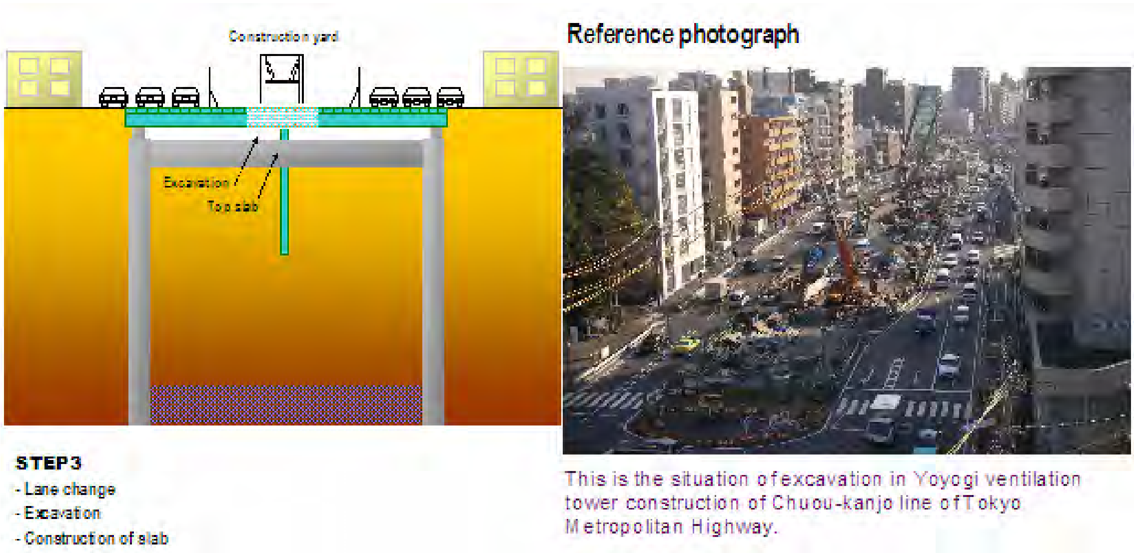
Source: JICA Study Team

Figure 4-193 Construction Procedure (2) of Typical Method



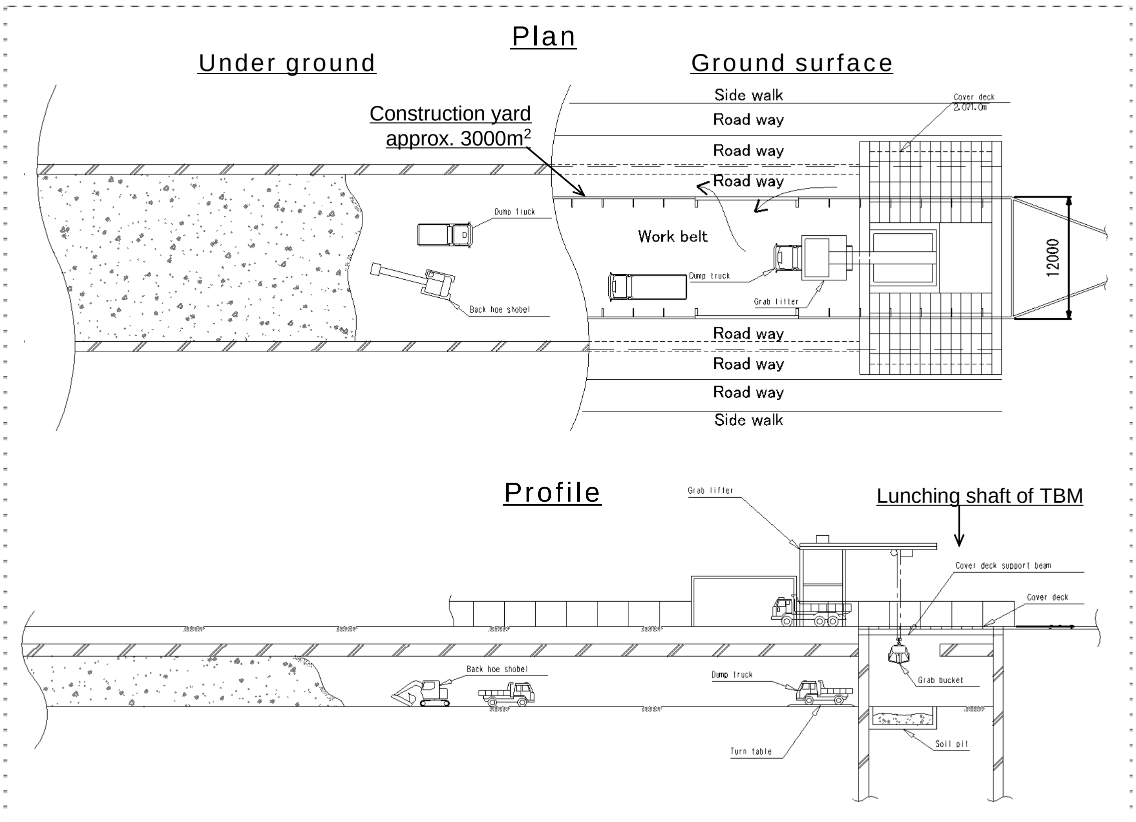
Source: JICA Study Team

Figure 4-194 Construction Yard for Diaphragm Wall



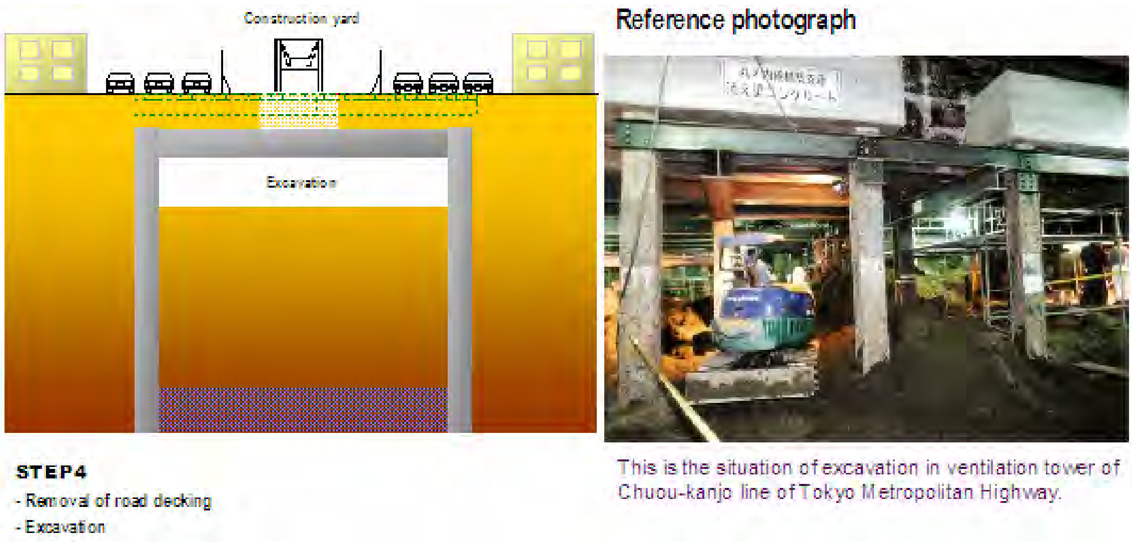
Source: JICA Study Team

Figure 4-195 Construction Procedure (3) of Typical Method



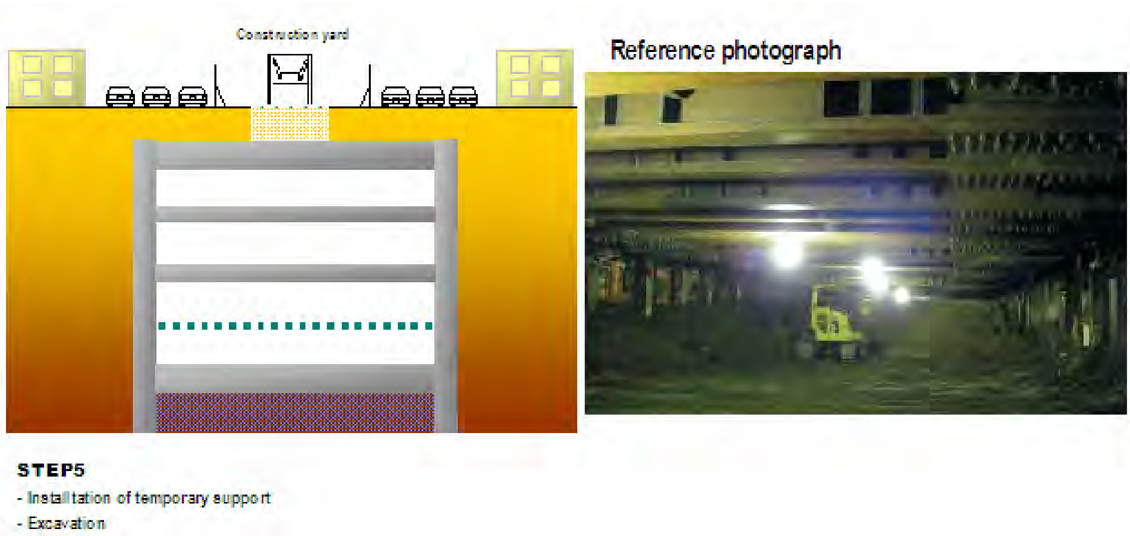
Source: JICA Study Team

Figure 4-196 Construction Yard for Excavation and Other Related Works



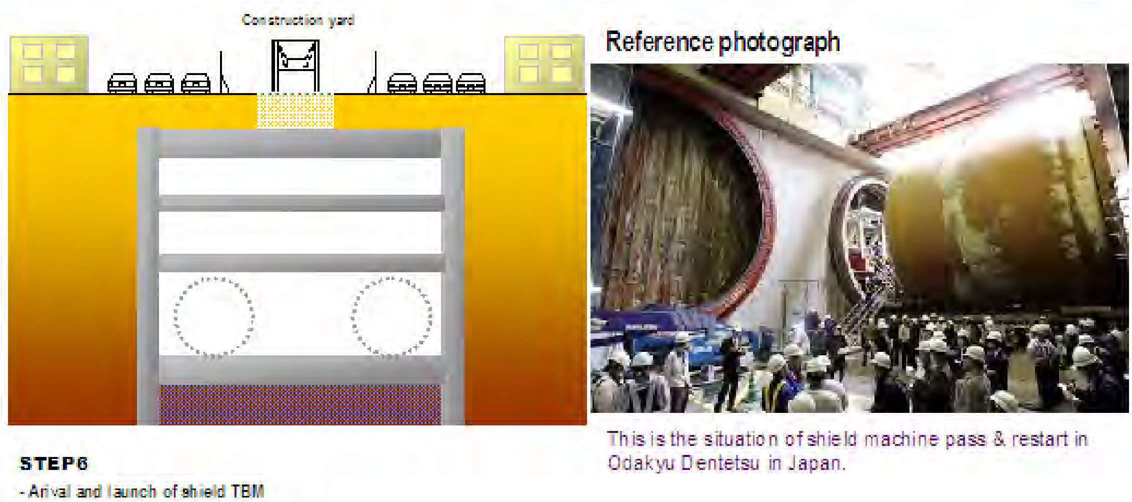
Source: JICA Study Team

Figure 4-197 Construction Procedure (4) of Typical Method



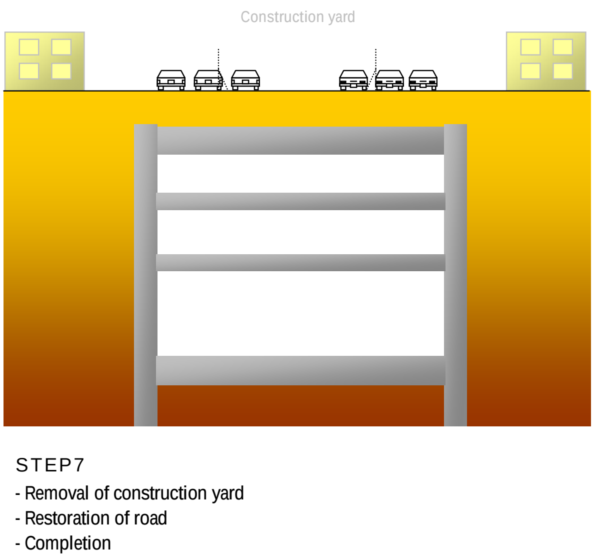
Source: JICA Study Team

Figure 4-198 Construction Procedure (5) of Typical Method



Source: JICA Study Team

Figure 4-199 Construction Procedure (6) of Typical Method



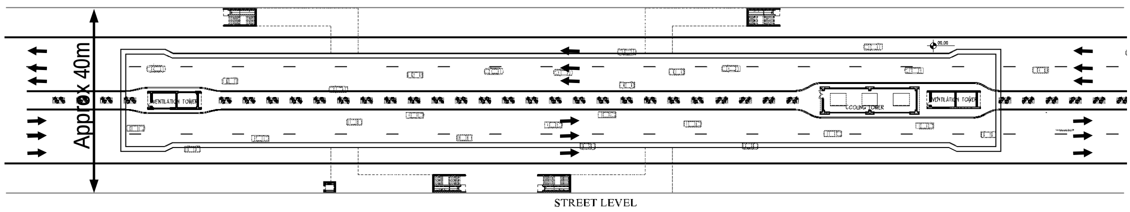
Source: JICA Study Team

Figure 4-200 Construction Procedure (7) of Typical Method

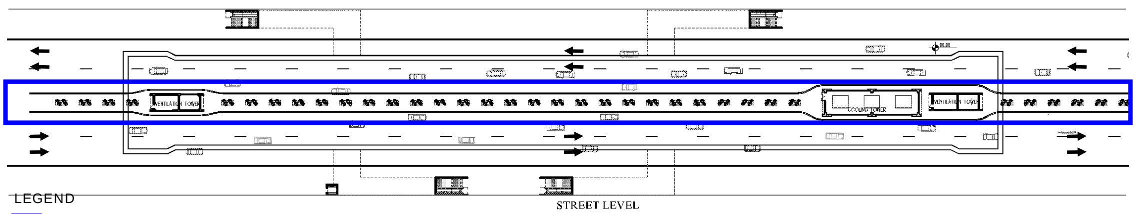
iii) Traffic Management

Typical traffic management plan during construction is shown in Figure 4-201 and Figure 4-202.

STEP1: Current traffic condition



STEP2: Removal median

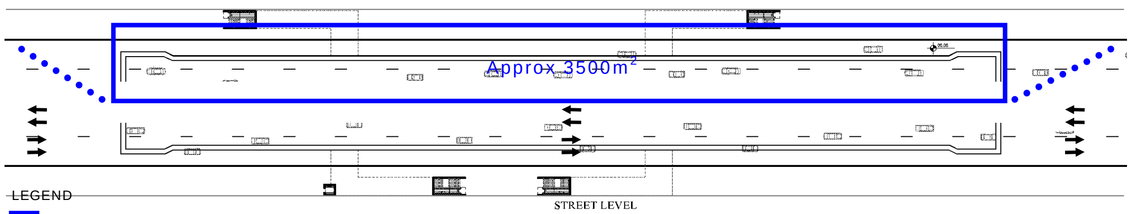


LEGEND

Construction yard

Road decking area

STEP3: Construction of Diaphragm wall and Road deck



LEGEND

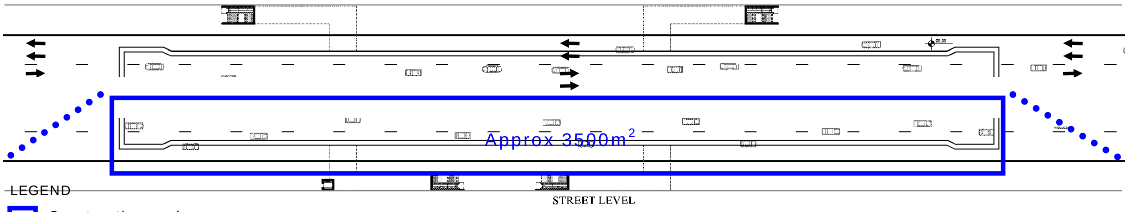
Construction yard

Road decking area

Source: JICA Study Team

Figure 4-201 Traffic Management Plan during Implementation of Procedure 1 to 3 of Typical Construction Method

STEP4: Construction of Diaphragm wall and Road deck

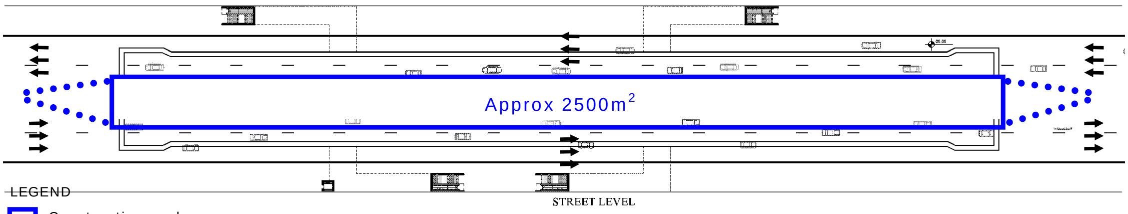


LEGEND

Construction yard

Road decking area

STEP5: Excavation, construction of slab

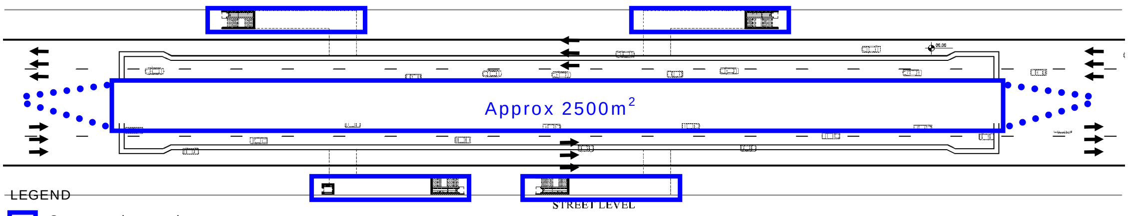


LEGEND

Construction yard

Road decking area

STEP6: Construction of annex structures

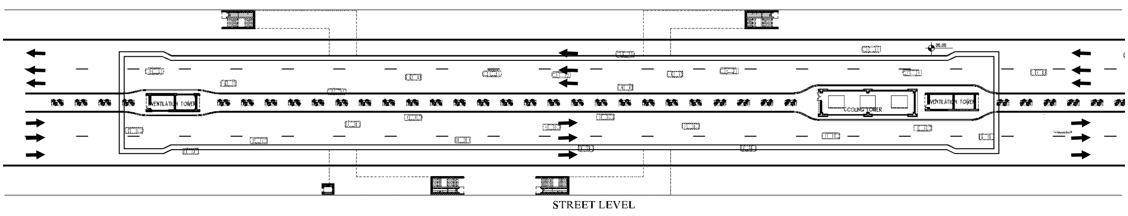


LEGEND

Construction yard

Road decking area

STEP7: Removal of road deck, Restoration of road and Completion



Source: JICA Study Team

Figure 4-202 Traffic Management Plan during Implementation of Procedure 5 to 7 of Typical Construction Method

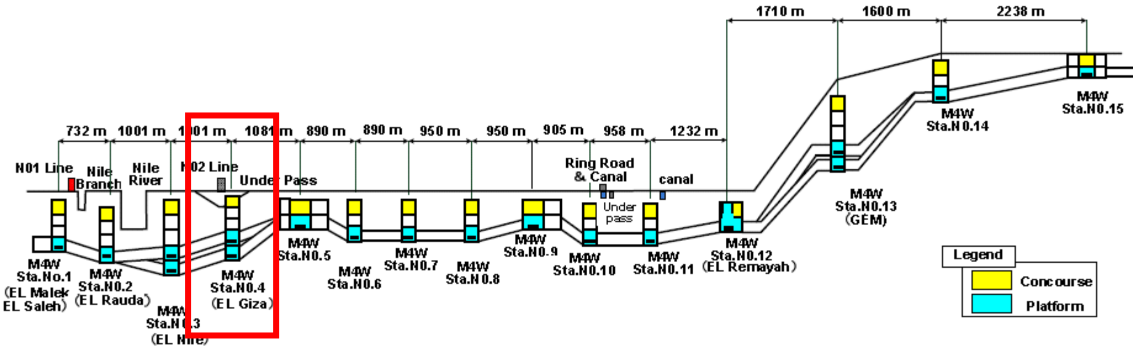
b) Study on Special Construction Method on Hard Point at Sta.No.4 (El-Giza)

i) Location and Consideration

Considerations for the special construction method are as follows:

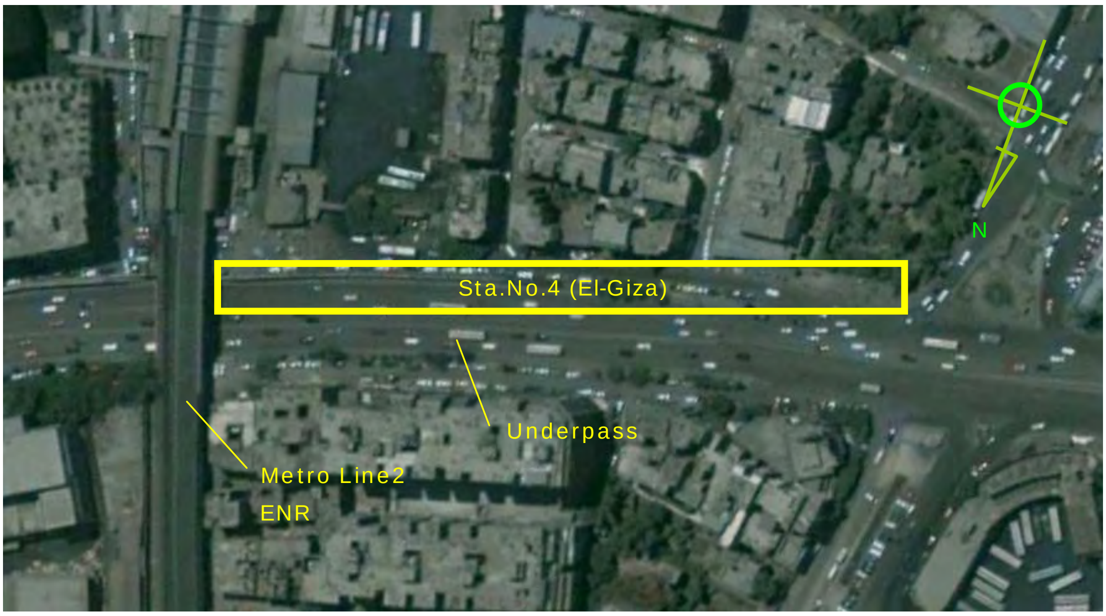
- Removal and restoration of existing retaining wall
- Construction of diaphragm wall on ground below groundwater level
- Construction in the vicinity of existing buildings
- Deep excavation (approx. GL-37 m) subject to high water pressure

The location of such construction is shown in Figure 4-203. The vicinity of the station is shown in Figure 4-204.



Source: JICA Study Team

Figure 4-203 Complex Location of Sta. No. 4 (El-Giza)



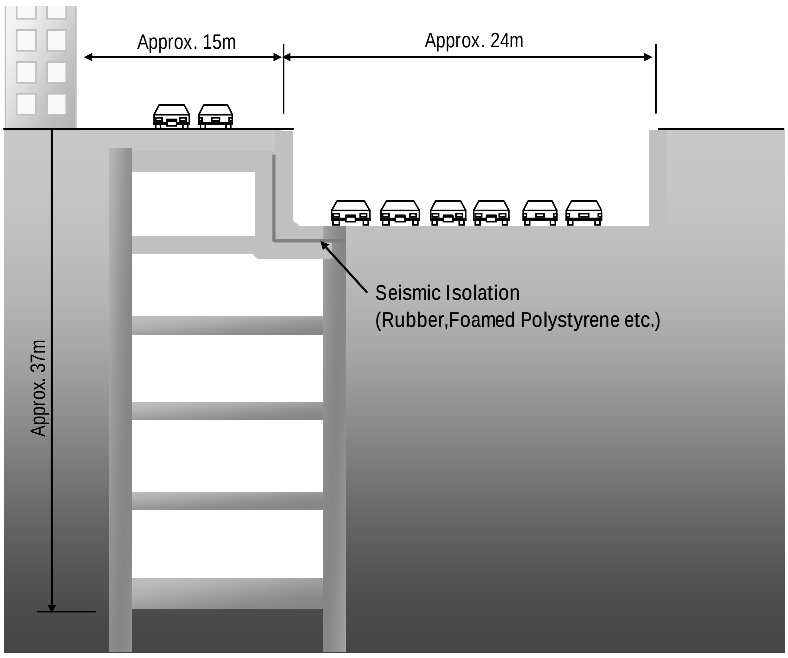
Source: JICA Study Team

Figure 4-204 Vicinity of Sta. No. 4 (El-Giza)

The present situation and cross section are shown in Figure 4-205 and Figure 4-206, respectively.

Source: JICA Study Team

Figure 4-205 Present situation at Location of Sta. No. 4 (El-Giza)



Source: JICA Study Team

Figure 4-206 Anticipated Completed Section of Sta. No. 4 (El-Giza)

Supplementary explanation regarding the structure

The issue on earthquake is one of the important considerations, The behaviour of the station and the retaining wall of the underpass during earthquake events will be different.

Therefore, both structures should be isolated using rubber or other similar material. Installation of such seismic isolation material is illustrated in Figure 4-206.

ii) Study on Procedure for Construction

Procedure for construction should be studied taking full conditions into account. Countermeasures for special consideration are as follows;

Regarding removal and restoration of existing retaining wall

- Observation method with movement sensor
- Removal and construction with appropriate procedure

Regarding construction of diaphragm wall on ground below groundwater level

As an auxiliary method, dewatering will be suitable considering cost and constructability. Fortunately, in this area, consolidation settlement due to dewatering is not expected to occur because the SPT-Value of clay soil in this area is more than ten according to the result of geological survey.

The following auxiliary methods of construction should be carried out in accordance with actual site condition:

- Artificial recharge method
- Soil improvement before construction of diaphragm wall
- Construction with stand pipe

Regarding construction in the vicinity of buildings

- Observation method

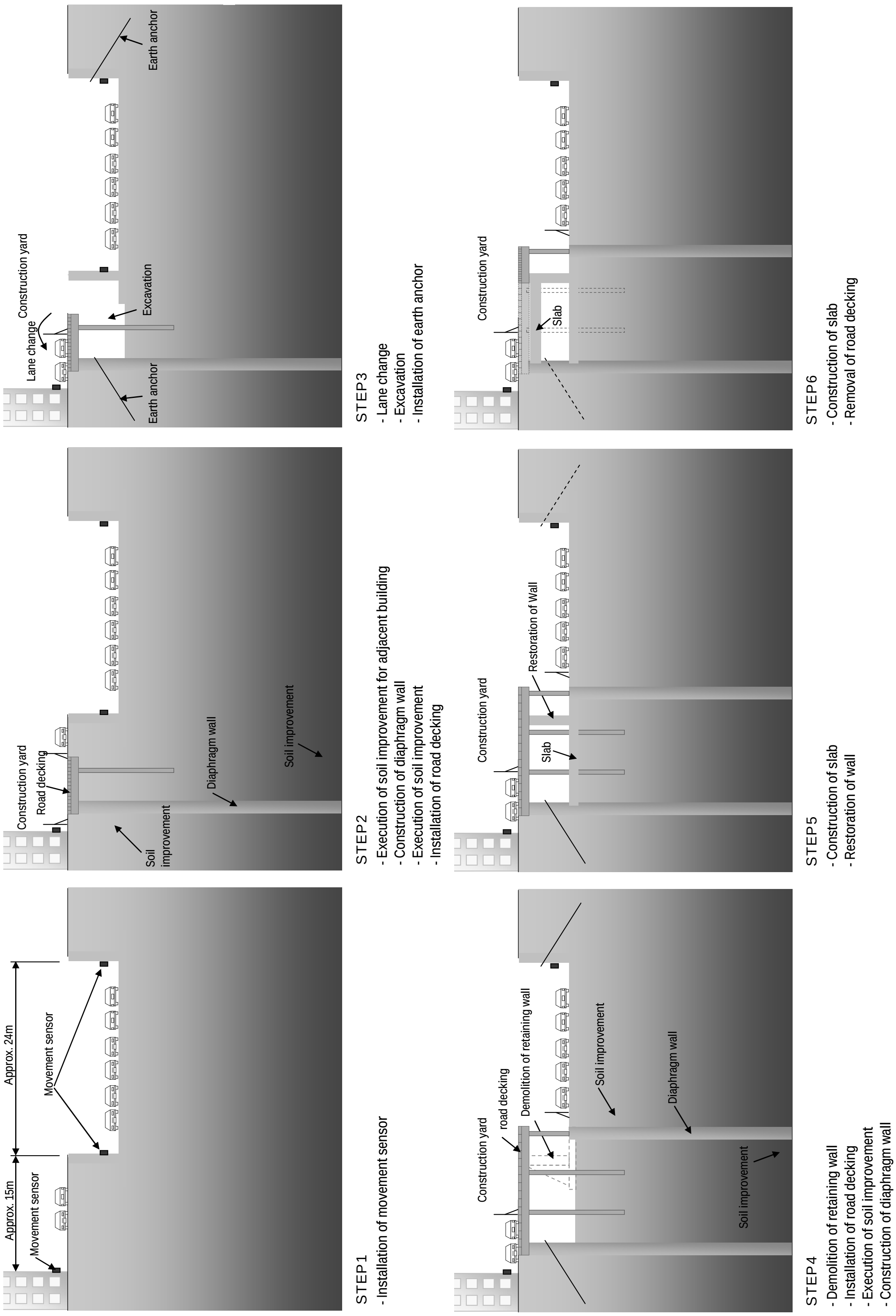
Regarding deep excavation at locations subject to high water pressure

- Soil improvement of embedded section of diaphragm wall before executing deep excavation
    - Column-Jet grout method is recommended as the most suitable soil improvement method for embedded section considering the following:
        - ✧ Depth of soil improvement is deeper than GL-35 m.
        - ✧ Period of improved effective should be longer than approx two years.
        - ✧ Deformation of ground should be reduced as much as possible.

Table 4-70 Comparison Table of Soil Improvement Method for Embedded Section of the Diaphragm Wall of Sta. No. 4

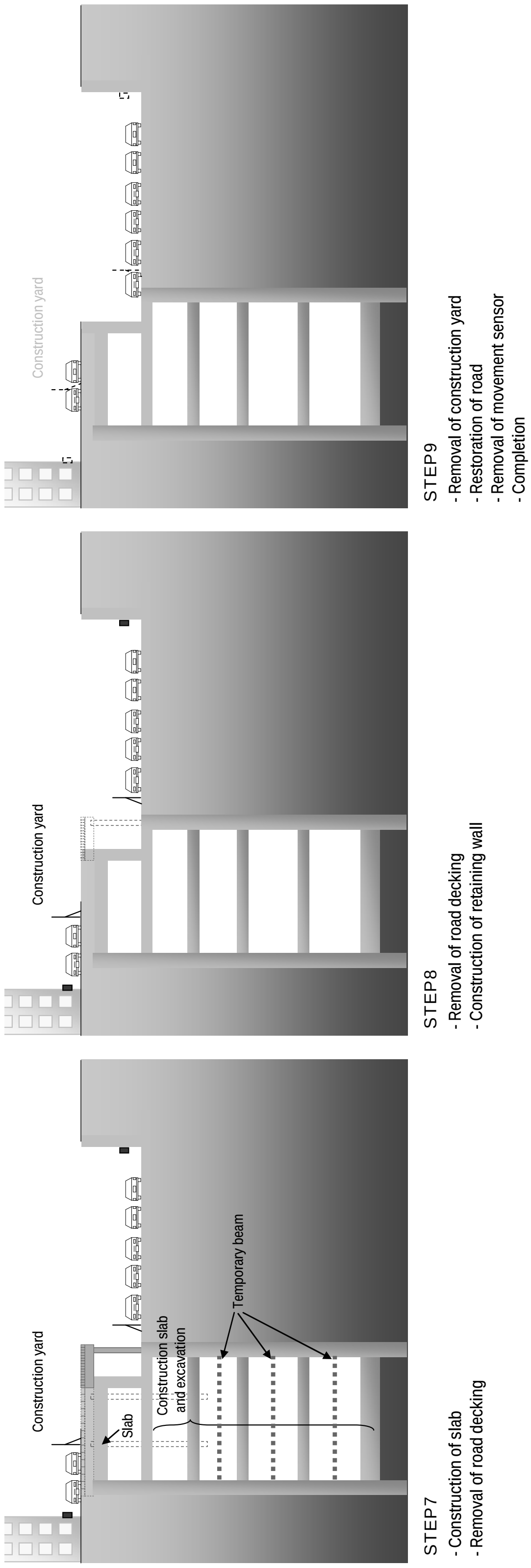
	Chemical Grouting Method	Jet Grouting Method	Column-Jet Grouting Method
Applicable Depth	Normally less than approximately 30 m.	Normally less than approximately 30 m	Normally less than approximately 60 m
Period of improved effective	Comparatively short	Comparatively long	Comparatively long
Improved strength	Comparatively low	Comparatively high	Comparatively high
Evaluation	Bad	Fair	Excellent

Considering above, the procedure for construction is shown in Figure 4-207 and Figure 4-208.



Source: JICA Study Team

Figure 4-207 Procedure (1) for the Construction of Sta. No.4

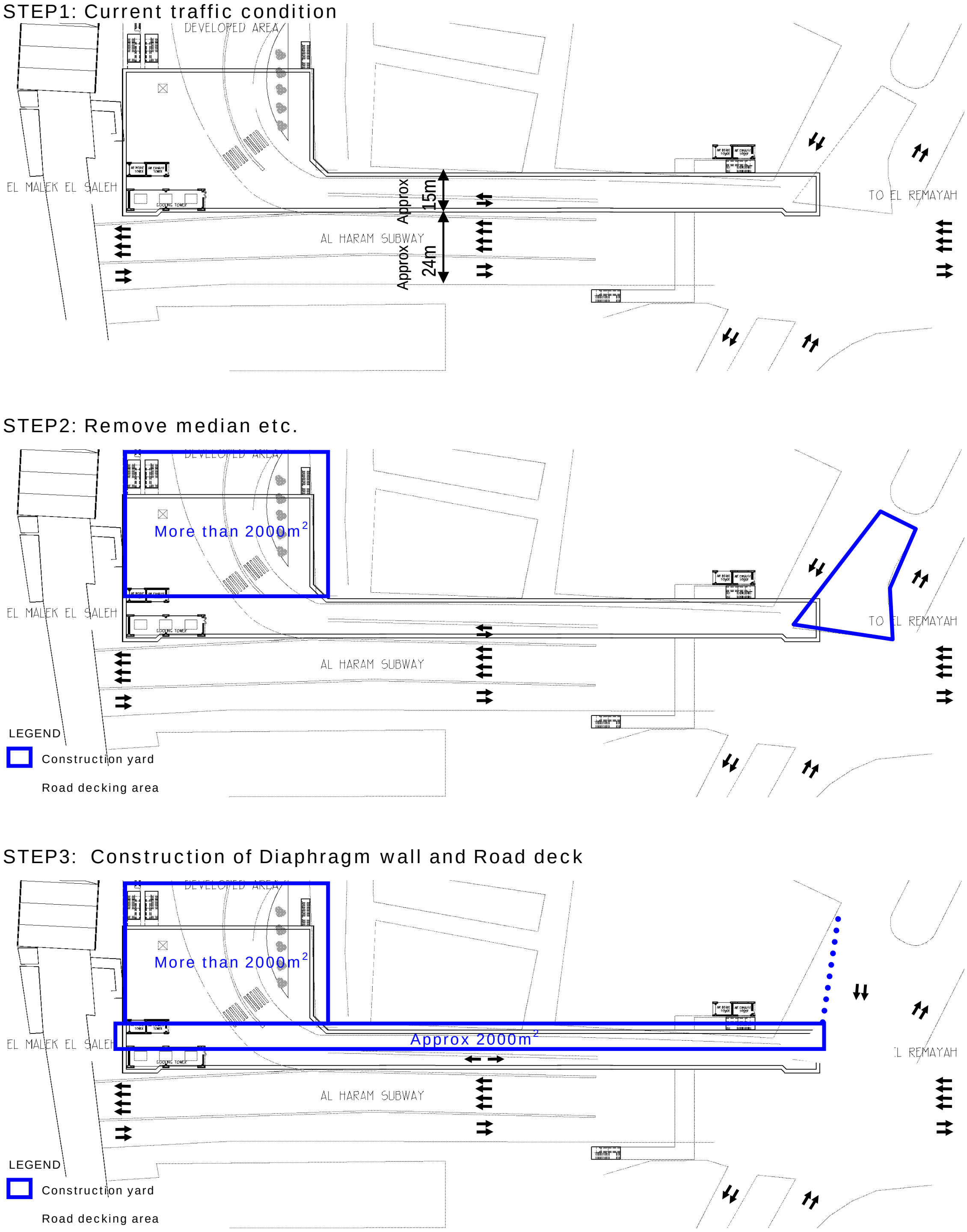


Source: JICA Study Team

Figure 4-208 Procedure (2) for the Construction of Sta. No.4

iii) Traffic Management

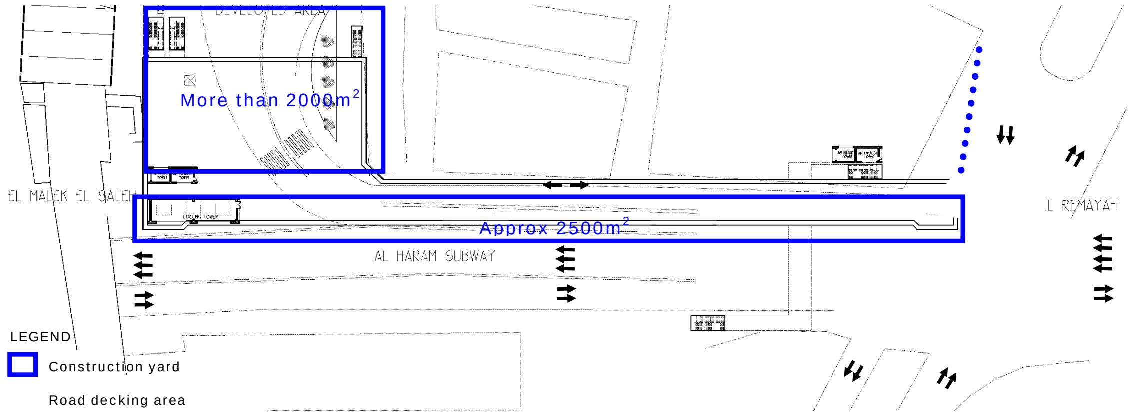
Conceptual traffic management plan during construction is shown in Figure 4-209 to Figure 4-211.



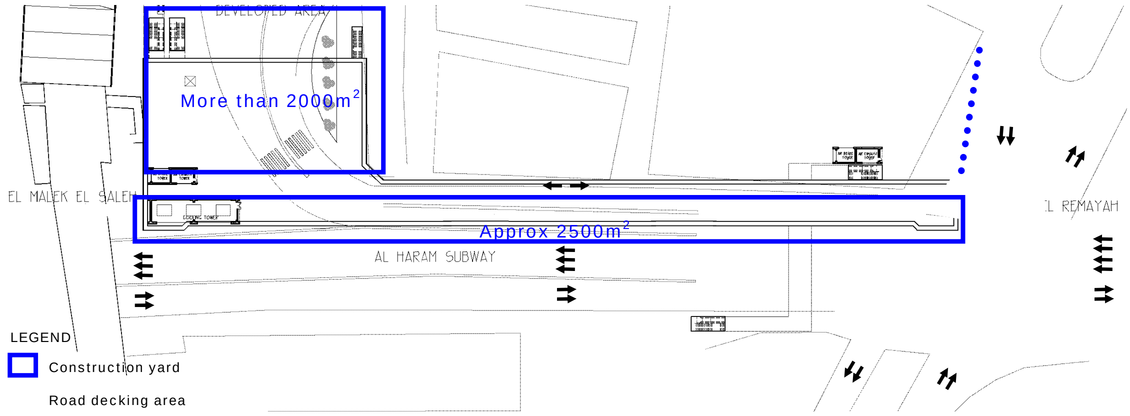
Source: JICA Study Team

Figure 4-209 Traffic Management Plan during Implementation of Procedure 1 to 3 for the Construction of Sta. No.4

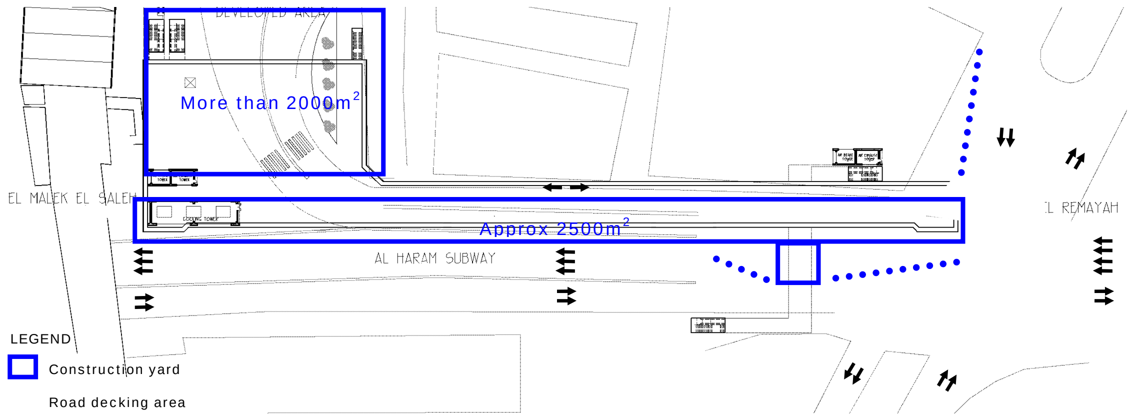
STEP4: Removal structre, installation dack and construction diaphragm wall



STEP5: Removal underpass structre, installation dack and construction of Diaphragm

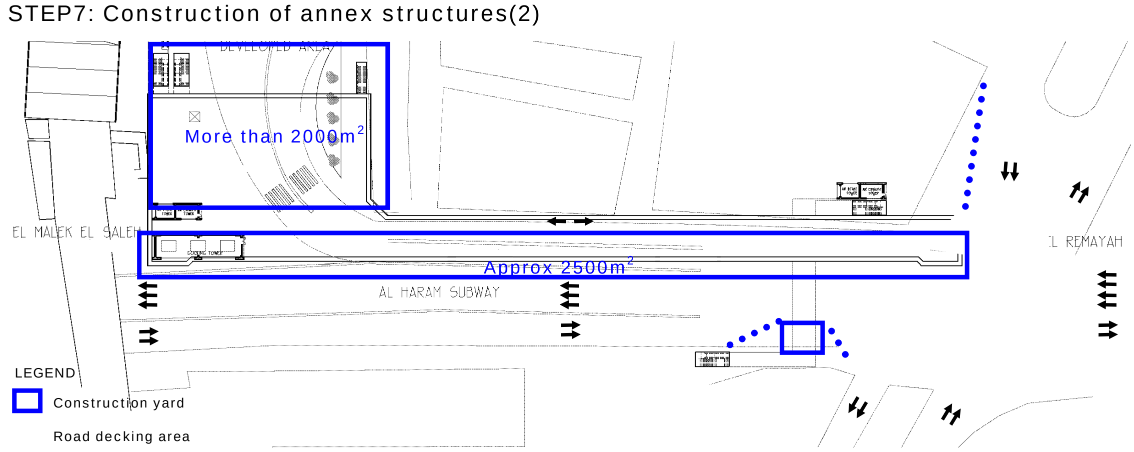


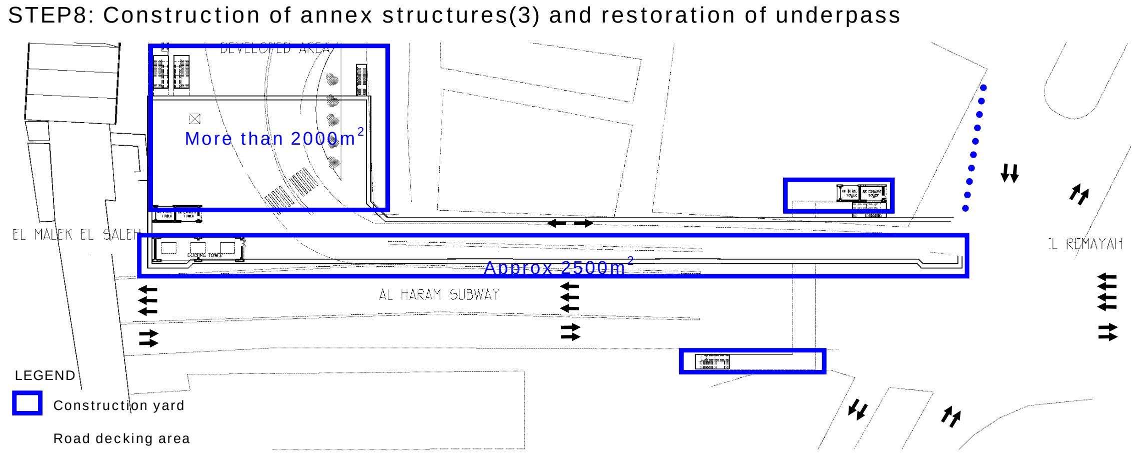
STEP6: Construction of annex structures(1)

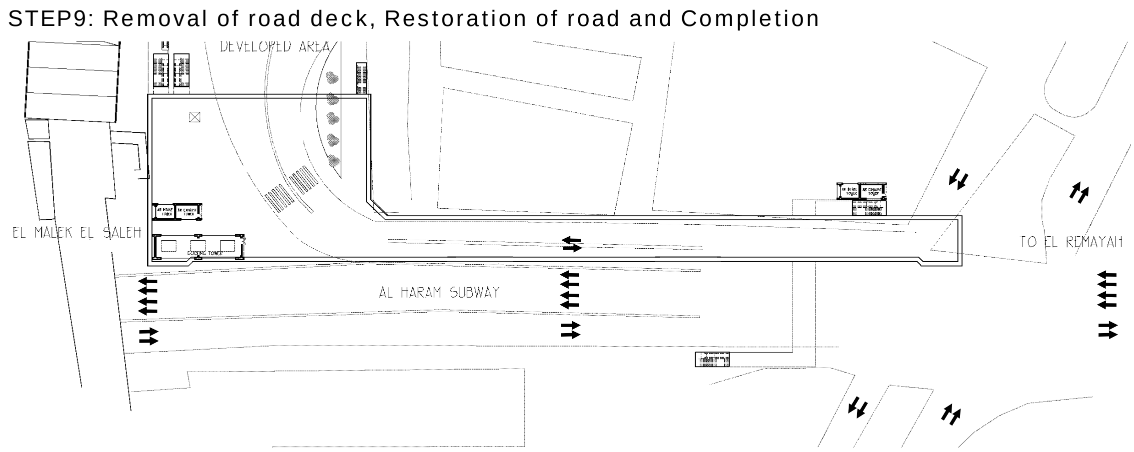


Source: JICA Study Team

Figure 4-210 Traffic Management Plan during Implementation of Procedure 5 to 6 for the Construction of Sta. No.4







Source: JICA Study Team

Figure 4-211 Traffic Management Plan during Implementation of Procedure 7 to 9 for the Construction of Sta. No. 4

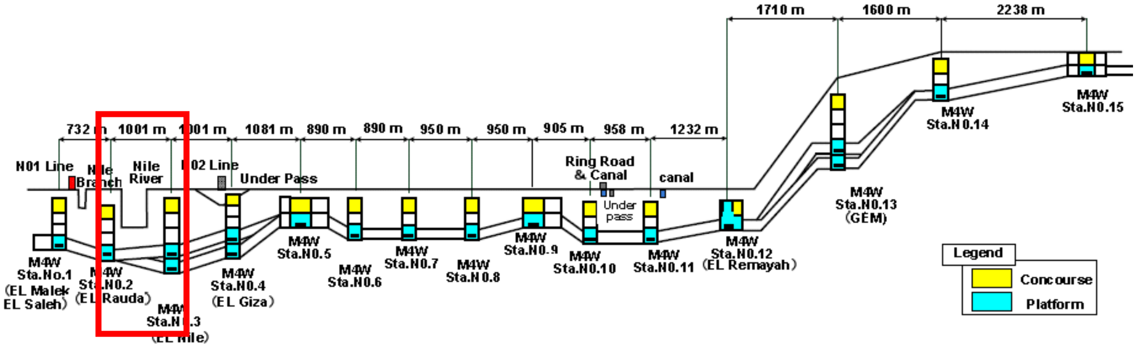
c) Study on Special Construction Method at Complex Location, Sta. No. 3 (El-Nile)

i) Location and Consideration

Considerations for the special construction method are as follows:

- Underpinning of El Giza Flyover
- Construction at the narrow space
- Construction under flyover (with minimum clearance of 5 m)
- Deep excavation (approx. GL-46 m) subject to high water pressure

The longitudinal location is shown in Figure 4-212 while the aerial photograph of the station location is shown in Figure 4-213.



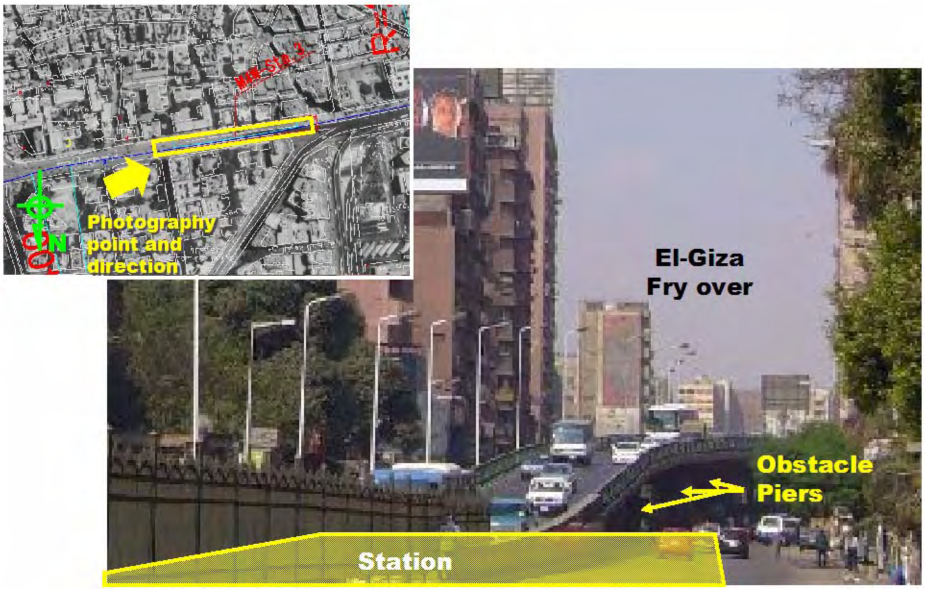
Source: JICA Study Team

Figure 4-212 Complex of Location of Sta. No. 3 (El-Nile)

Source: JICA Study Team

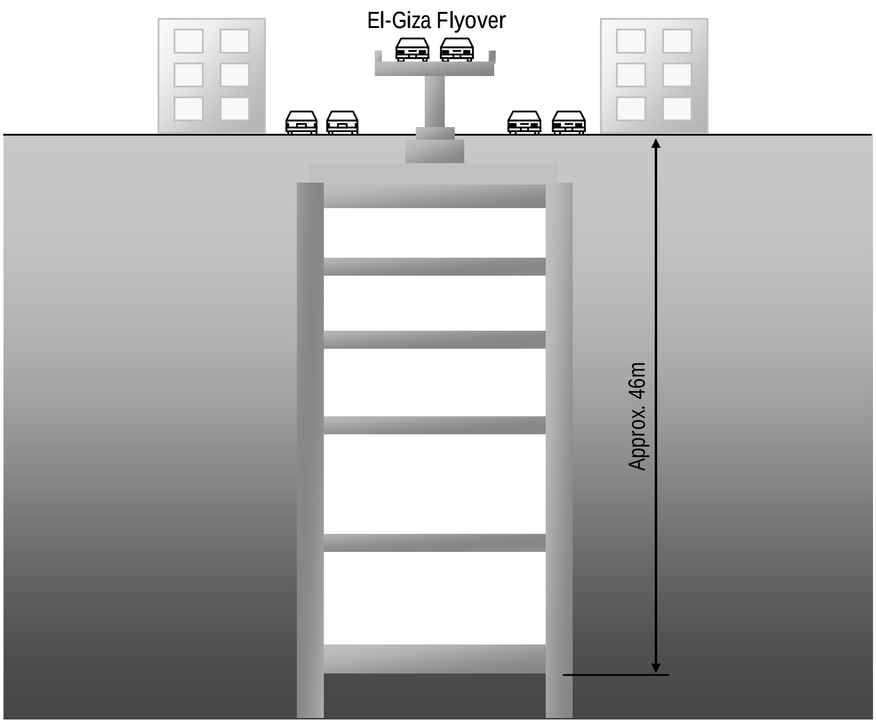
Figure 4-213 Vicinity of Sta. No. 3 (El-Nile)

The present situation and cross section is shown Figure 4-214 and Figure 4-215 respectively.



Source: JICA Study Team

Figure 4-214 Present Situation of Sta. No. 3 (El-Nile)



Source: JICA Study Team

Figure 4-215 Anticipated Completed Section of Sta. No. 3 (El-Nile)

ii) Study on Procedure of Construction

The procedure for construction should be studied taking all special considerations into account. Countermeasures for such special considerations are as follows:

Regarding underpinning of El Giza Flyover

- Observation method with movement sensor

Regarding construction at narrow space

- Observation method
- Use special equipment shown in Figure 4-216.

Source: JICA Study Team

Figure 4-216 Special Equipment (Portal Frame) for Construction of Diaphragm Wall at Narrow Road

Regarding construction under flyover (with minimum clearance of 5 m)

- Observation method
- Use special equipment shown in **Figure** 4-217.

Source: BMX Catalogue

Figure 4-217 Special Equipment, BMX, for Construction of Diaphragm Wall

Regarding deep excavation subject to high water pressure

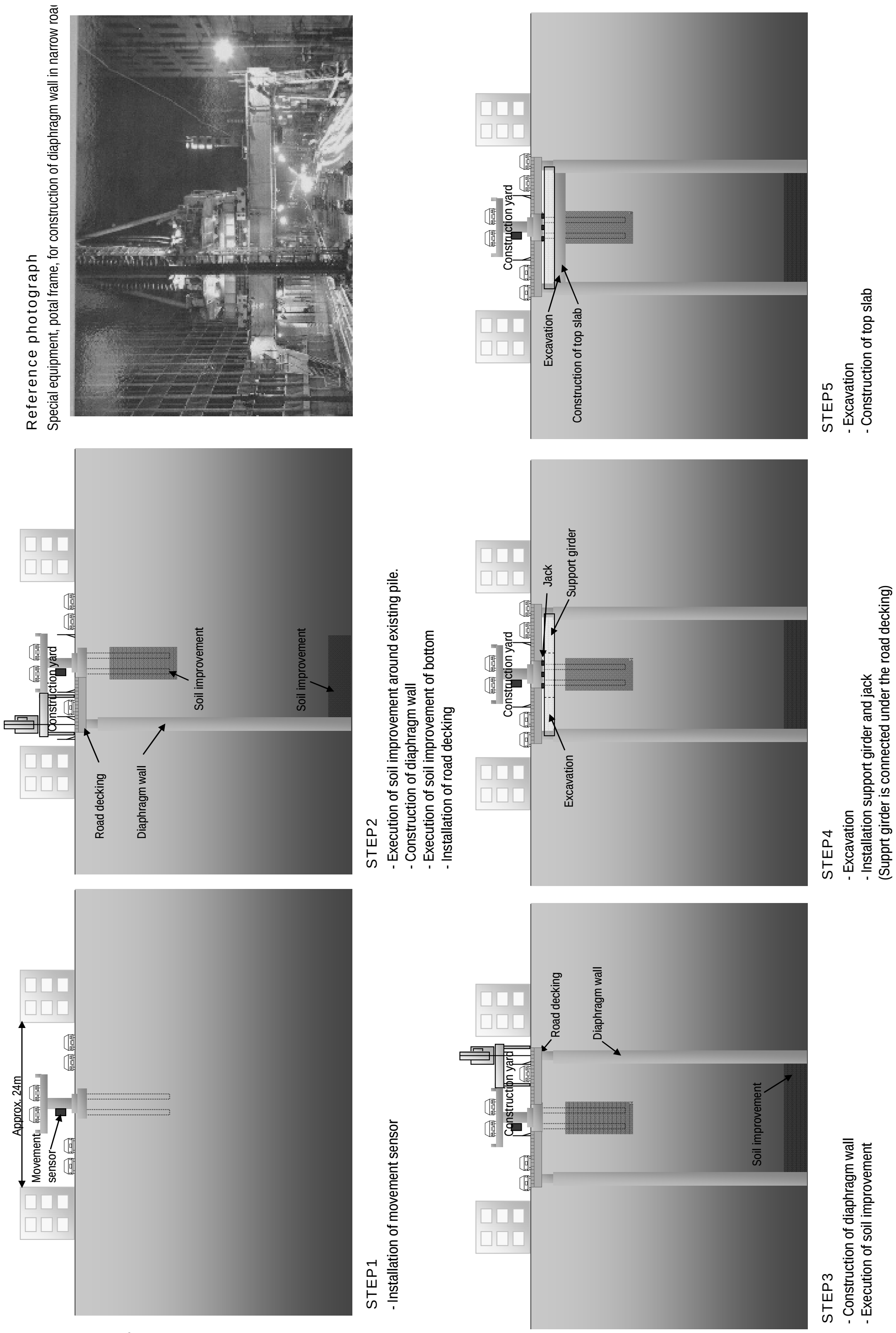
- Soil improvement of embedded section of diaphragm wall prior to deep excavation
    - Column-jet grout method is recommended as the most suitable soil improvement method for the embedded section, considering the following:
        - ✧ Depth of soil improvement is deeper than GL-35 m.
        - ✧ Soil improvement should be effective for more than approximately two years.
        - ✧ Deformation of ground should be reduced as much as possible.

Table 4-71 Comparison Table of Soil Improvement Method for Embed Section of the Diaphragm Wall of Sta. No. 3

	Chemical Grouting Method	Jet Grouting Method	Column-Jet Grouting Method
Applicable Depth	Normally less than approx 30m.	Normally less than approx.30m	Normally less than approx. 60m
Period of improved effective	Comparatively short	Comparatively long	Comparatively long
Improved strength	Comparatively low	Comparatively high	Comparatively high
Evaluation	Bad	Fair	Excellent

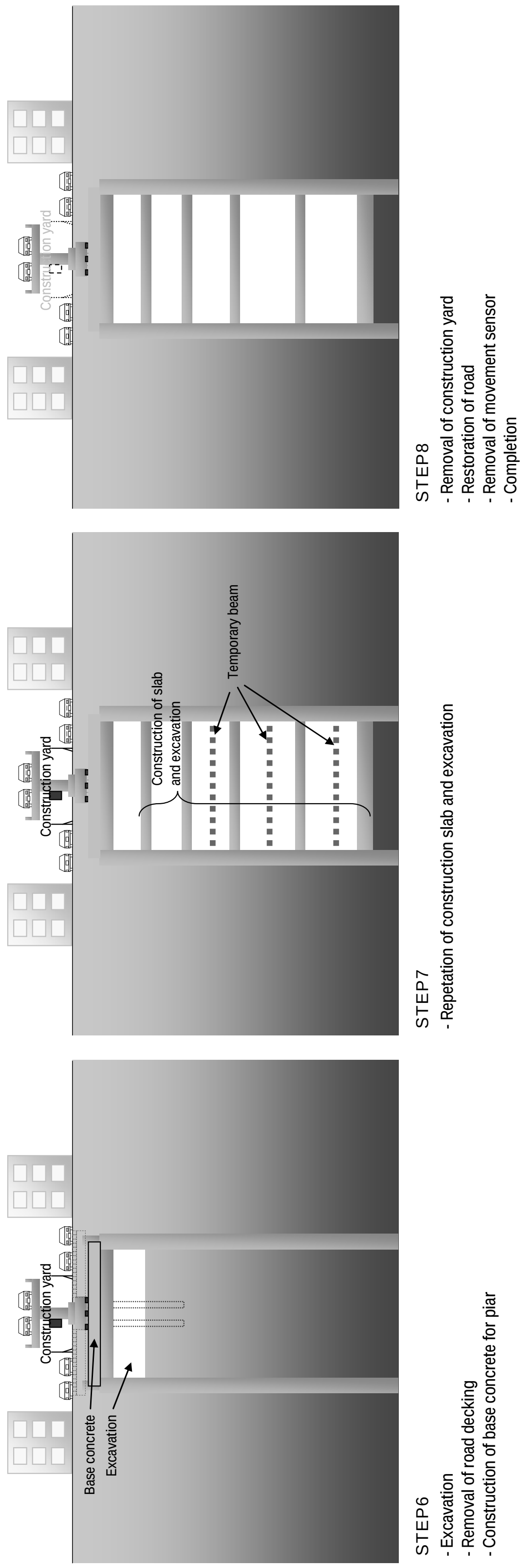
Source: JICA Study Team

Considering above, the procedure for construction is shown in Figure 4-218 and Figure 4-219.



Source: JICA Study Team

Figure 4-218 Procedure 1 to 5 for the Construction of Sta. No. 3

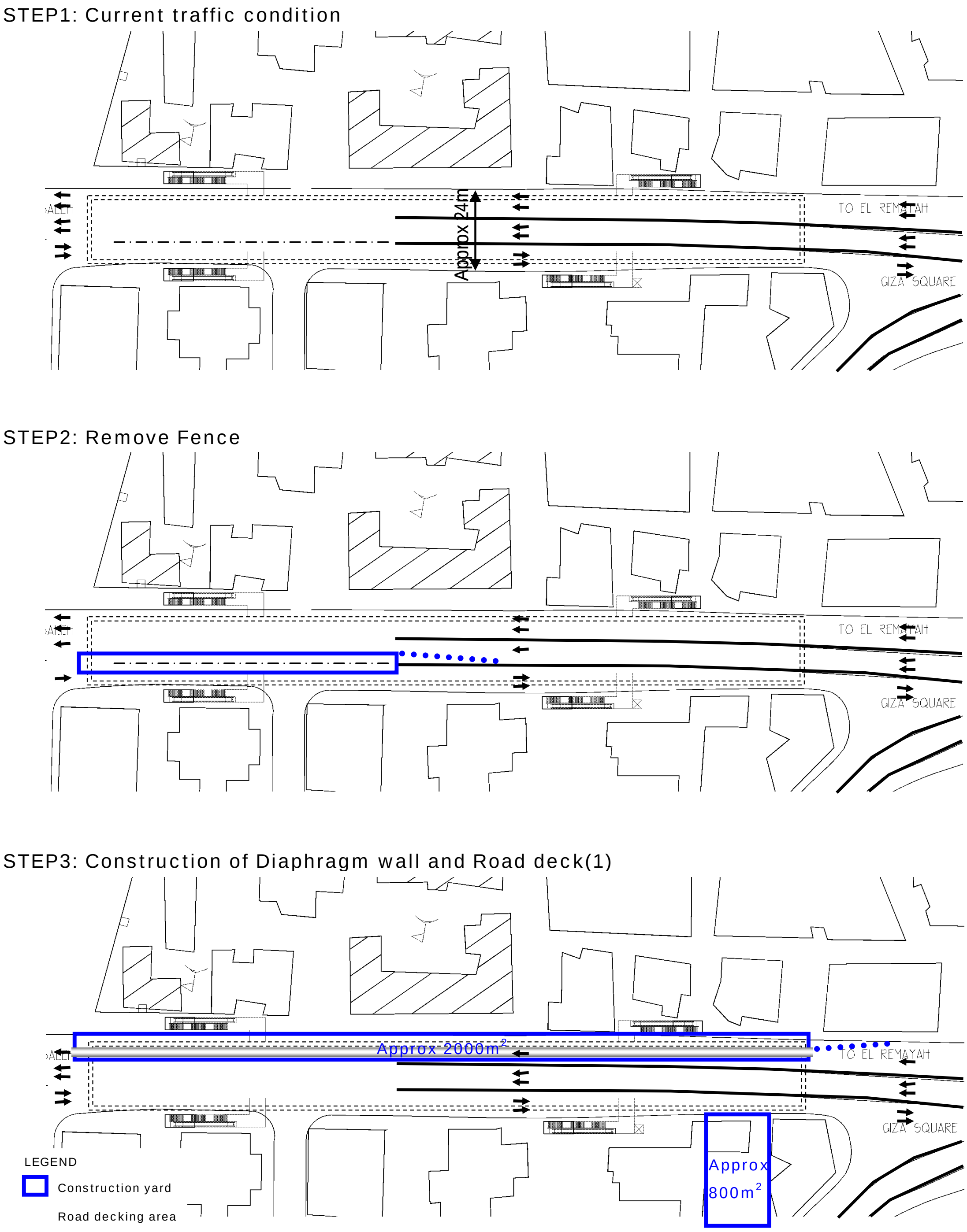


Source: JICA Study Team

Figure 4-219 Procedure 6 to 8 for the Construction of Sta. No. 3

iii) Traffic Management

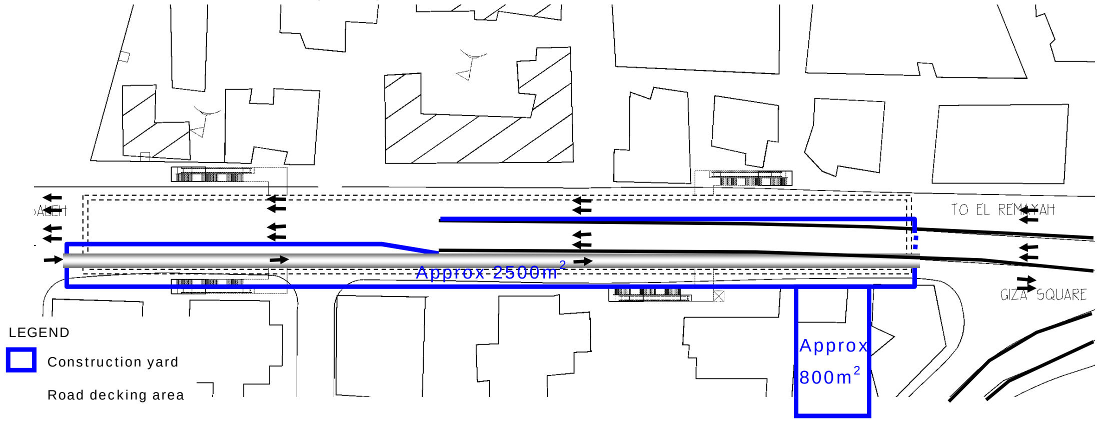
Conceptual traffic management plan during construction is shown in Figure 4-220 to Figure 4-222.



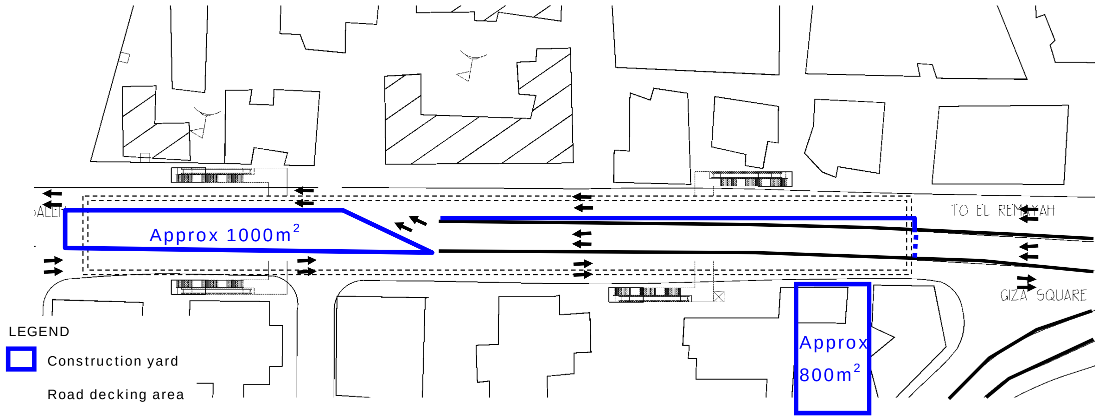
Source: JICA Study Team

Figure 4-220 Traffic Management Plan during Implementation of Procedure 1 to 3 for the Construction of Sta. No. 3

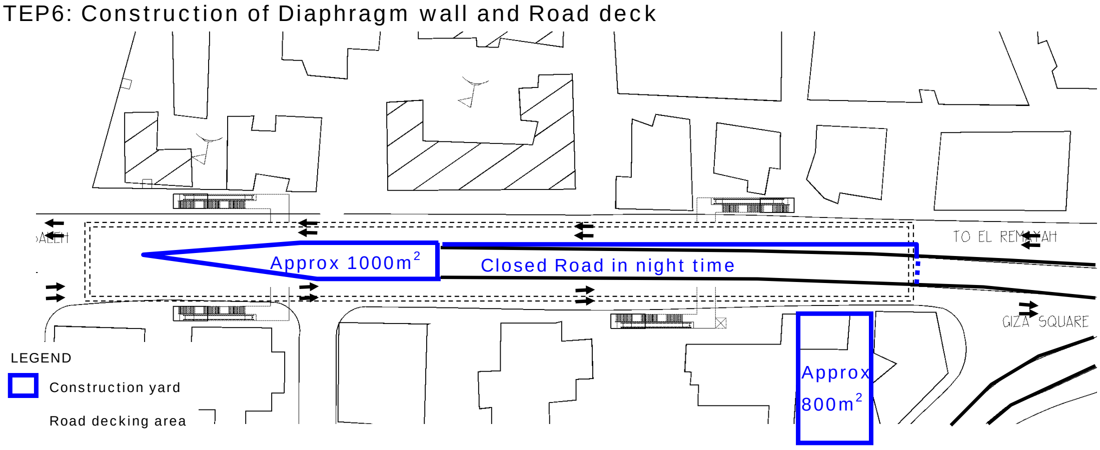
STEP4: Construction of Diaphragm wall and Road



STEP5: Construction of Diaphragm wall and Road



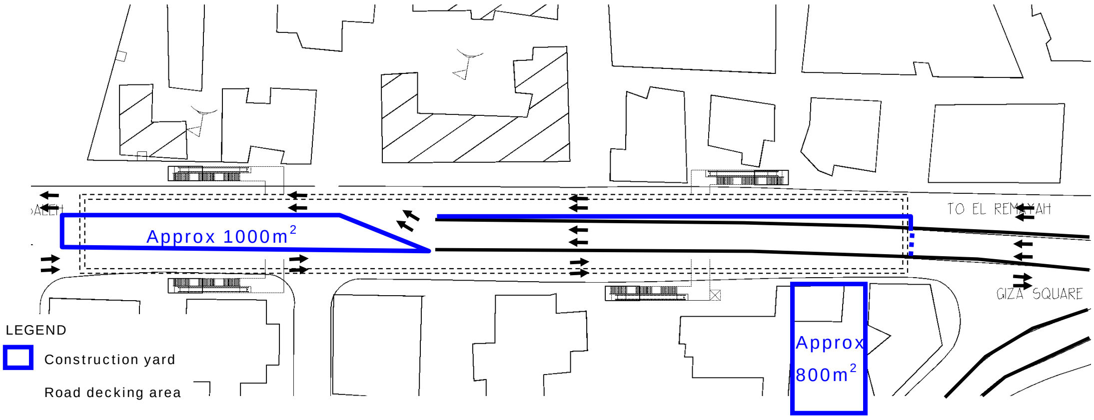
STEP6: Construction of Diaphragm wall and Road deck



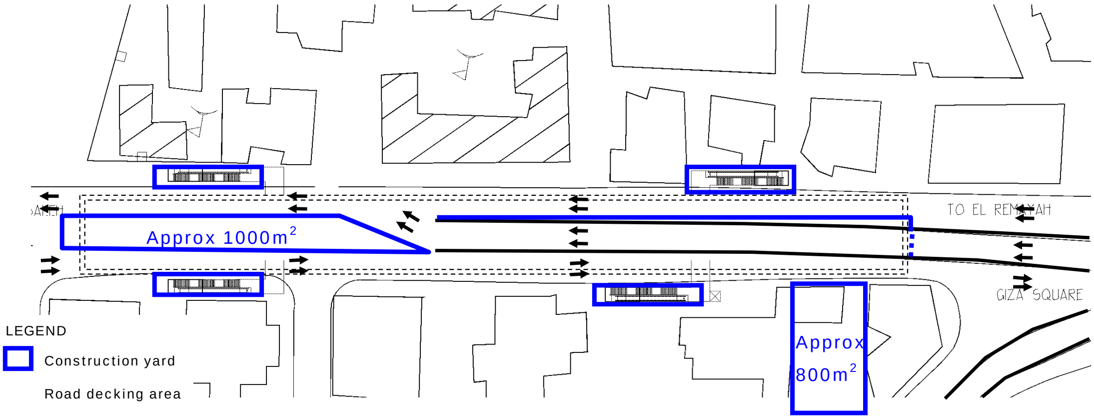
Source: JICA Study Team

Figure 4-221 Traffic Management Plan during Implementation of Procedure 4 to 6 for the Construction Sta. No. 3

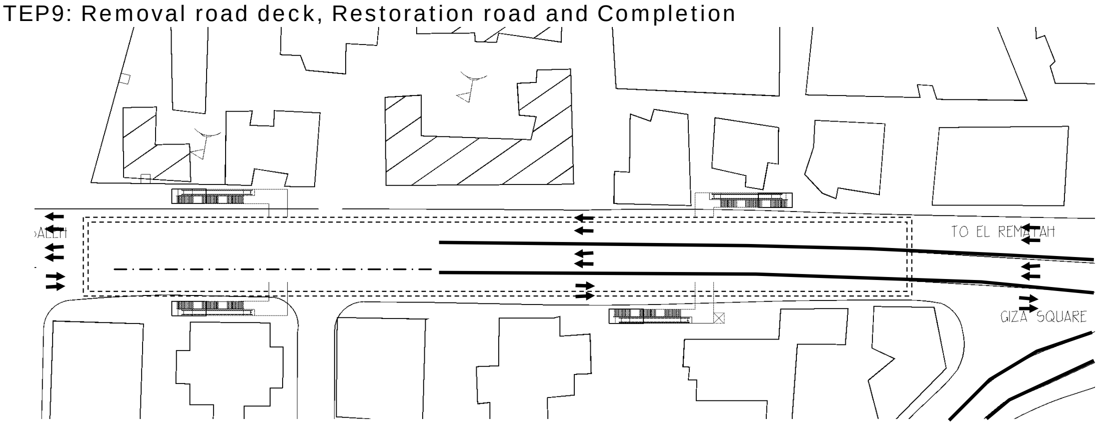
STEP7: Excavation, construction of slab and underpinning etc.



STEP8: Construction of annex structures



STEP9: Removal road deck, Restoration road and Completion



Source: JICA Study Team

Figure 4-222 Traffic Management Plan during Implementation of Procedure 7 to 9 for the Construction of Sta. No. 3

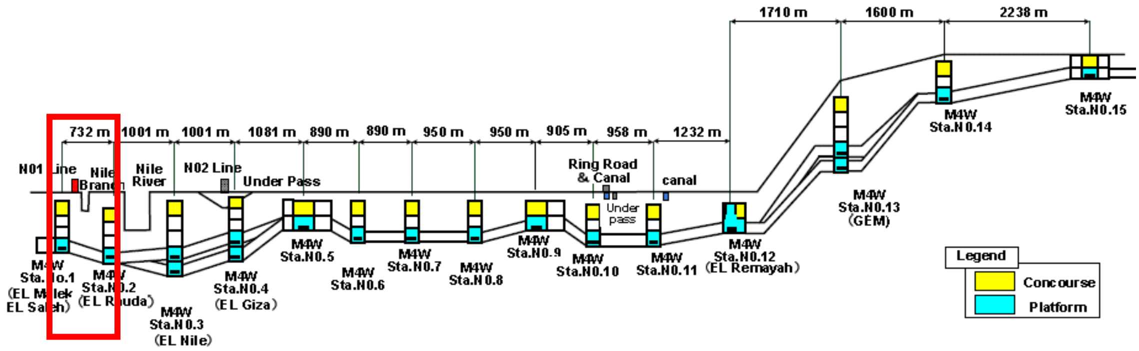
d) Study on Special Construction Method at Complex Location, Sta. No. 2 (El-Rauda)

i) Location and Consideration

Considerations for the special construction method are as follows:

- Obstructing buildings (Flat, Gas Station, Food Shop)
- Deep excavation (approx. GL-46m) subject to high water pressure

The longitudinal location is shown in Figure 4-223 while the aerial photograph of the station location is shown in Figure 4-224.



Source: JICA Study Team

Figure 4-223 Complex Location of Sta. No. 2 (El-Rauda)

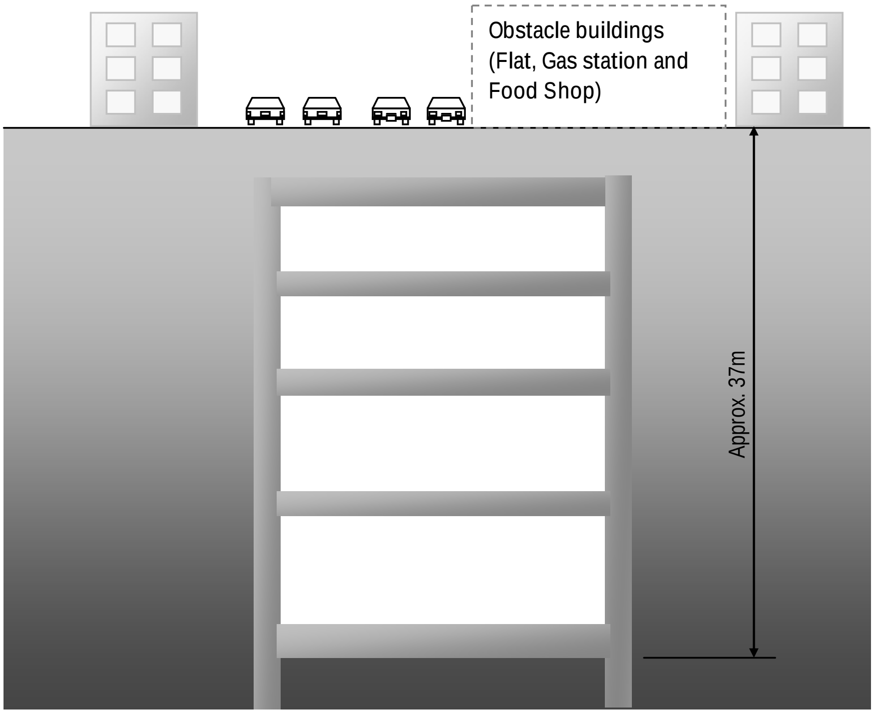
Source: JICA Study Team

Figure 4-224 Vicinity of Sta. No. 2 (El-Rauda)

The present situation and cross section is shown in Figure 4-225 and Figure 4-226, respectively.

Source: JICA Study Team

Figure 4-225 Present situation of Sta. No. 2 (El-Rauda)



Source: JICA Study Team

Figure 4-226 Anticipated Completed Section of Sta. No. 2 (El-Rauda)

ii) Study on Procedure for Construction

Procedure for construction should be studied taking all special considerations into account. Countermeasures for such special consideration are as follows:

Regarding obstructing buildings (Flat, Gas Station, Food Shop)

The most suitable construction method is studied from the perspective of social impact, constructability and cost of construction and land acquisition. Alternative construction methods to be applied are as follows.

- Cut-and-Cover Method without Underpinning
- Cut-and-Cover Method with Underpinning for important structure (Flat)
- Non-Cut-and-Cover Method, Pre-Shell Method
- Non-Cut-and-Cover Method, Multi Face Shield Tunneling Method

Regarding above construction methods, a comparison table is shown in Table 4-72. As described in said table, the cut-and-cover method is recommended for both cases. In case land acquisition of important structure (flat) is impossible, the cut-and-cover method with underpinning for important structure (flat) will be recommended.

Table 4-72 Comparison Table of Construction Method for Sta. No. 2

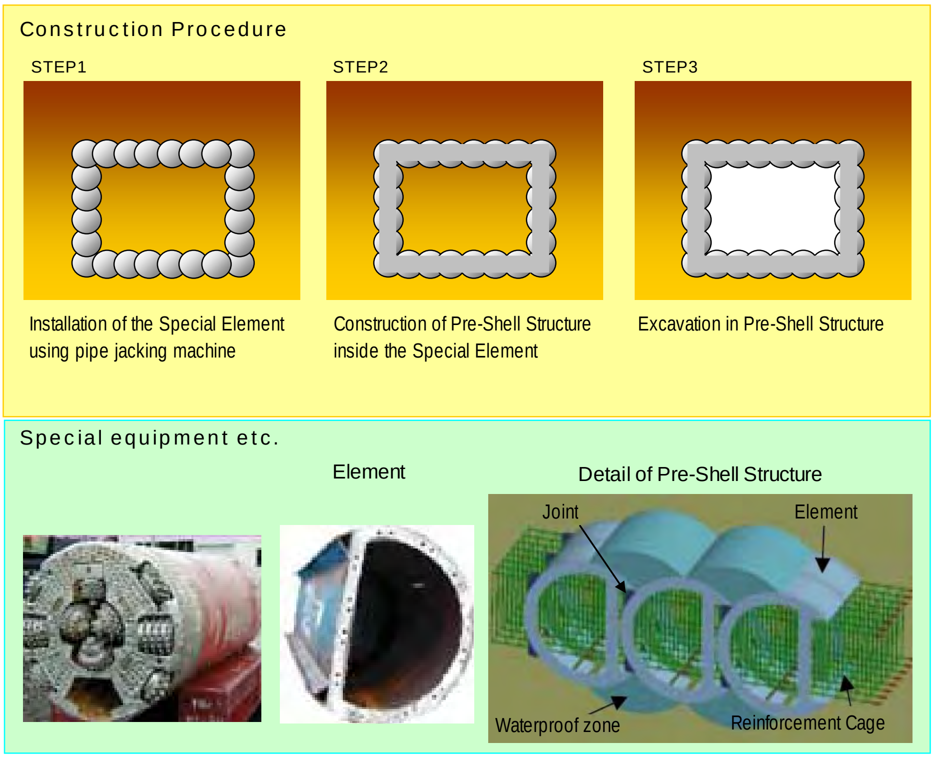
Construction method	Cut and Cover		Non-Cut and Cover	
	Without underpinning	With underpinning for important structure*)	Pre-shell Method	Multi Face Shield Tunneling Method
Impact to Social environment	Need the land acquisition of three buildings crossing station (+)	Need the land acquisition of 2 buildings crossing station (++)	No need the land acquisition of 3 buildings crossing station (+++)	No need the land acquisition of 3 buildings crossing station (+++)
Constructivity	Nomal cut and cover method (+++)	Cut and cover method with underpinning of 1 buildings (+)	No need underpinning and something like that. (++)	No need underpinning and something like that. (++)
Cost Ratio of construction and land acquisition	Base cost 1.00 (Base) (+++)	A bit expensive approx.1.05 (+++)	Expensive approx.1.15 (++)	Expensive over.2.00 (+)
Upper construction cost ratio Lower Land acquisition cost ratio	(0.87) (0.13)	(approx. 1.00) (approx. 0.05)	(approx. 1.15) (0.00)	(over 2.00) (0.00)
Total Evaluation	Excellent	Excellent	Good	Fair

Note: Evaluation= Good <-- +++ , ++ , + --> Poor
*) Important structure is flat or Mosqu.

Source: JICA Study Team

Non-Cut-and-Cover Method, Pre-Shell Method

The pre-Shell method is one of the advance technologies for underground development. The outline of this construction method is shown in Figure 4-227.

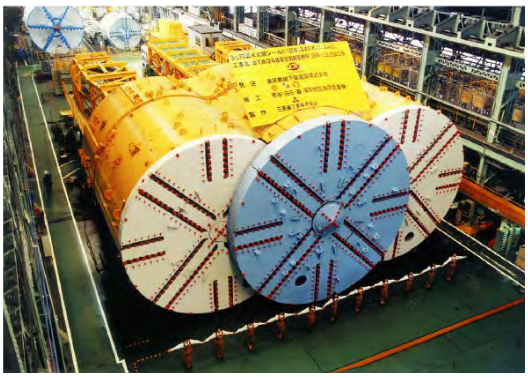


Source: Japanese Contractor

Figure 4-227 Pre-Shell Method

Non-Cut-and-Cover Method, Multi Face Shield Tunnelling Method

Multi face shield tunnelling method is also one of the advance technologies in underground construction. Figure 4-228 shows multi face shield TBM used in the construction of IIDABASHI Station in Tokyo, Japan.



Source: JICA Study Team

Figure 4-228 Multi Face Shield TBM

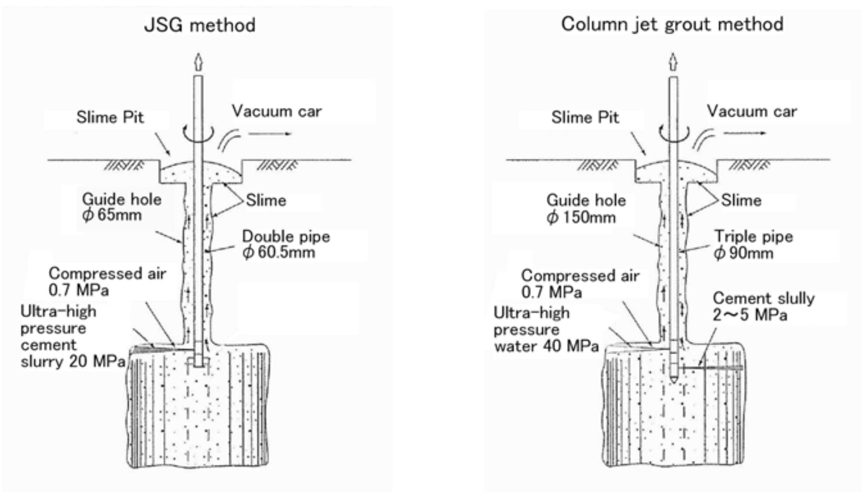
<u>Regarding Deep excavation in high water pressure</u>

- Soil improvement of embed section of diaphragm wall before deep excavation
    - Column-jet grout method is recommended as the most suitable soil improvement method for embedded section considering the following:
        - ✧ Depth of soil improvement is deeper than GL-35 m.
        - ✧ Soil improvement should be effective for more than approx two years.
        - ✧ Deformation of ground should be reduced as much as possible.

Table 4-73 Comparison Table of Soil Improvement Method for the Embed Section of the Diaphragm Wall of Sta. No. 2

	Chemical Grouting Method	Jet Grouting Method *)	Column-Jet Grouting Method *)
Applicable Depth	Normally less than approx 30m.	Normally less than approx.30m	Normally less than approx. 60m
Period of improved effective	Comparatively short	Comparatively long	Comparatively long
Improved strength	Comparatively low	Comparatively high	Comparatively high
Evaluation	Bad	Fair	Excellent

*) Note: JSG method and Column jet grout method is explained in the following figure.



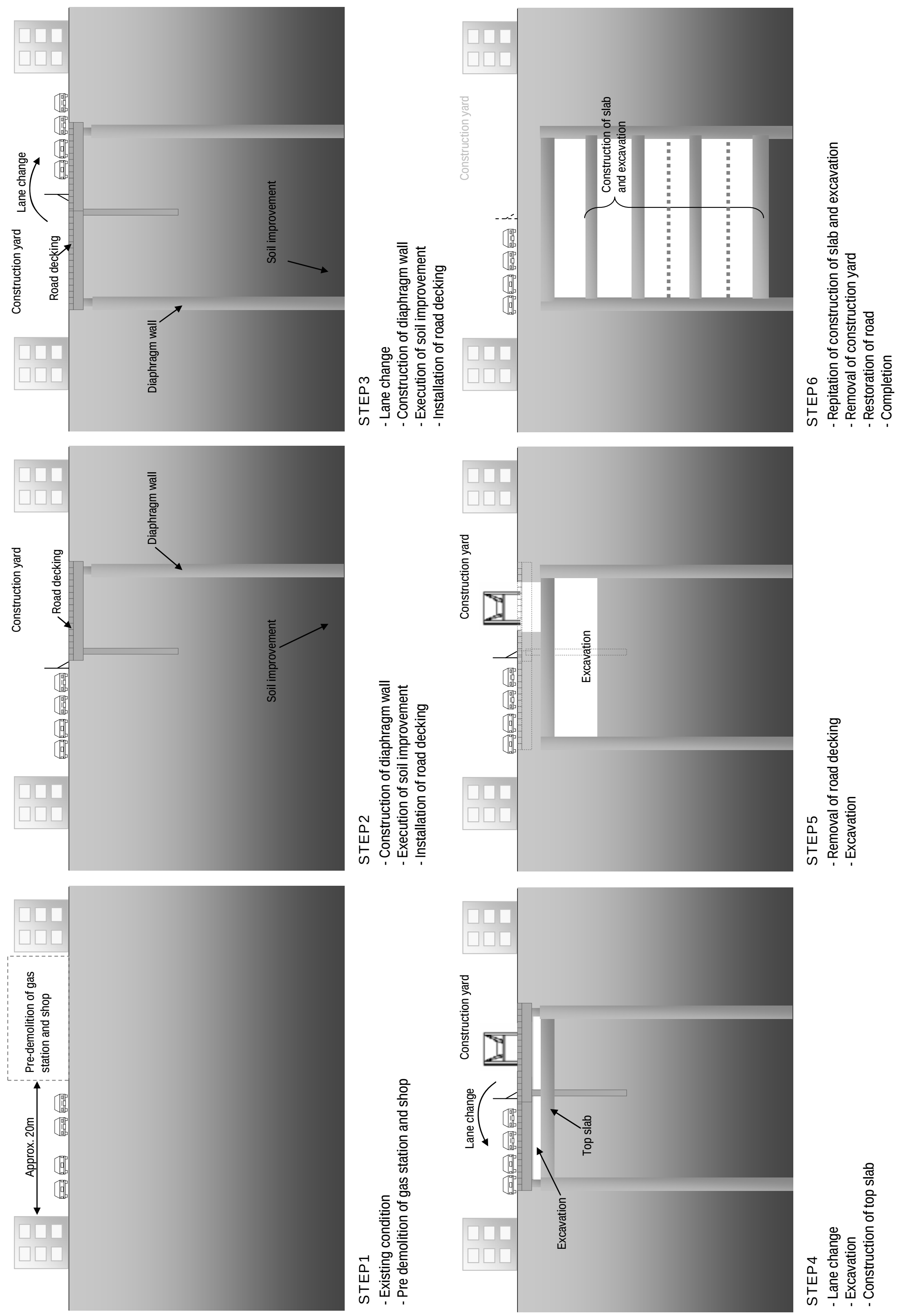
JSG method cuts, mixes and replaces the ground with compressed air and high pressure cement slurry by the double pipe to create columns of stabilized soil.

Column jet grout method cuts the ground with compressed air and high pressure water and replaces with cement slurry by the triple pipe to create columns of stabilized soil.

Figure 4-229 JSG Method and Column Jet Grout Method

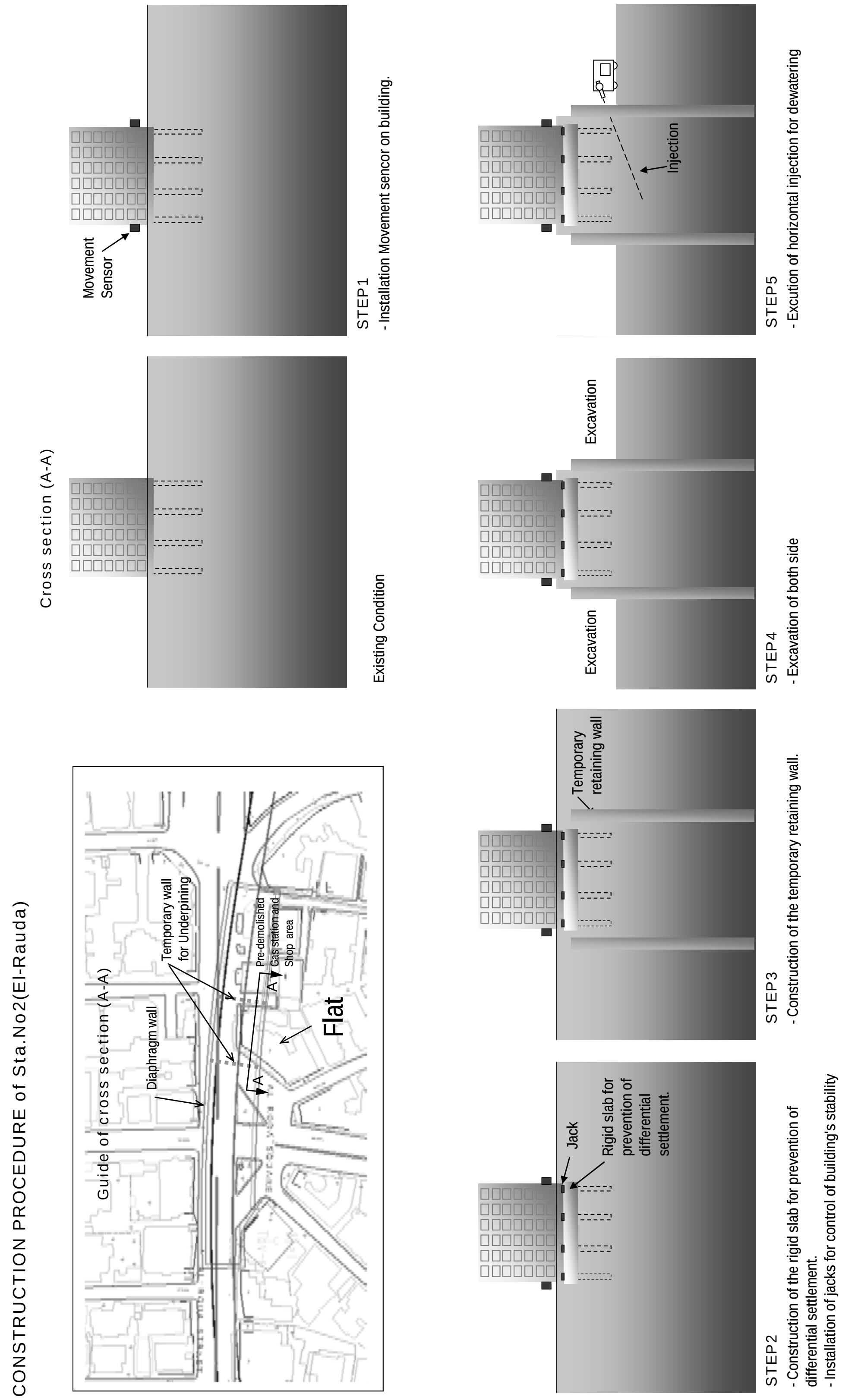
Considering above, the procedure for construction is shown in Figure 4-230.

Additionally, the procedure for underpinning buildings (flats) is shown in Figure 4-231 and Figure 4-232.



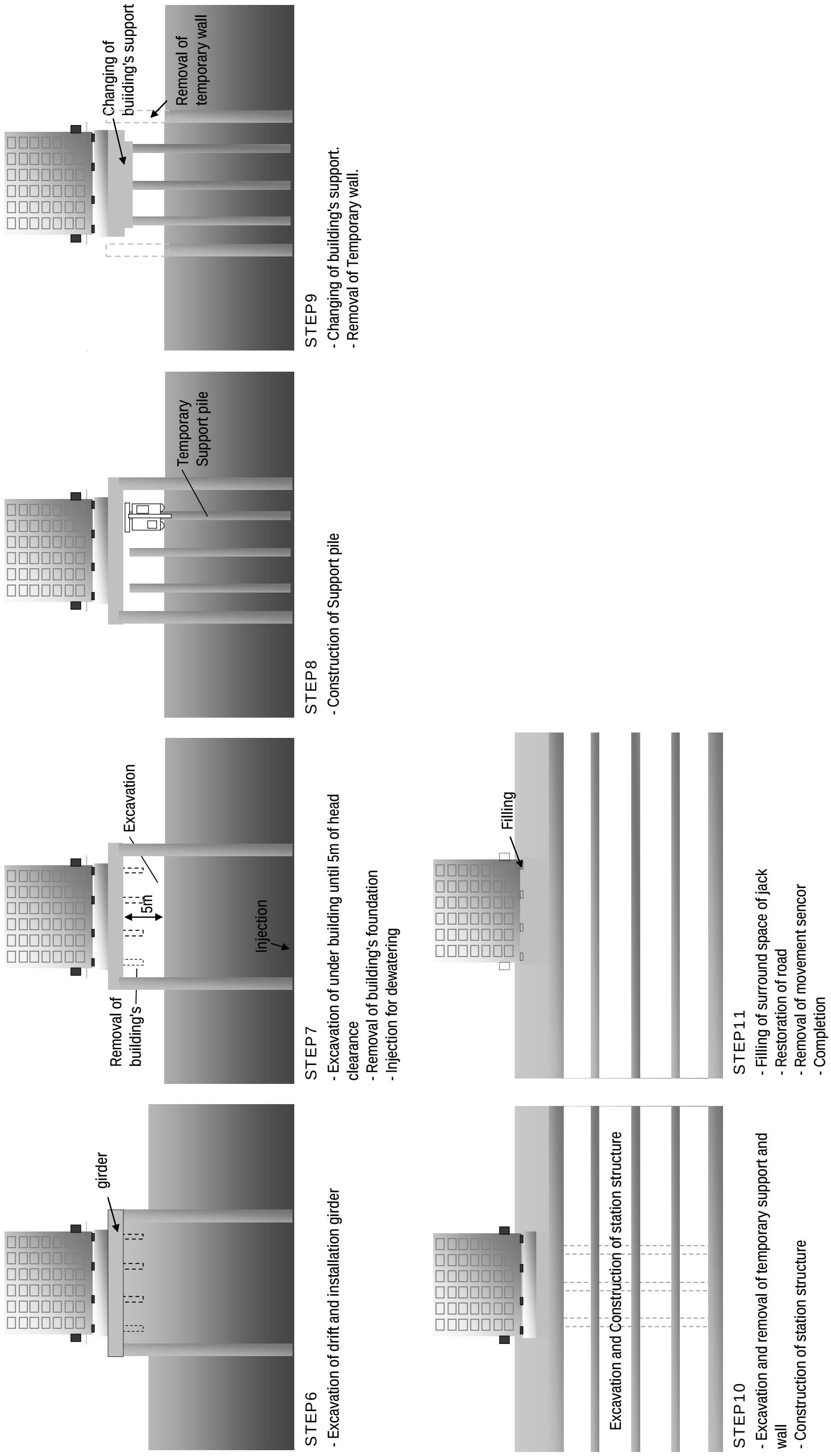
Source: JICA Study Team

Figure 4-230 Procedure for Construction of Sta. No. 2: Standard Section



Source: JICA Study Team

Figure 4-231 Procedure 1 to 5 for the Construction of Sta. No. 2: Underpinning Section

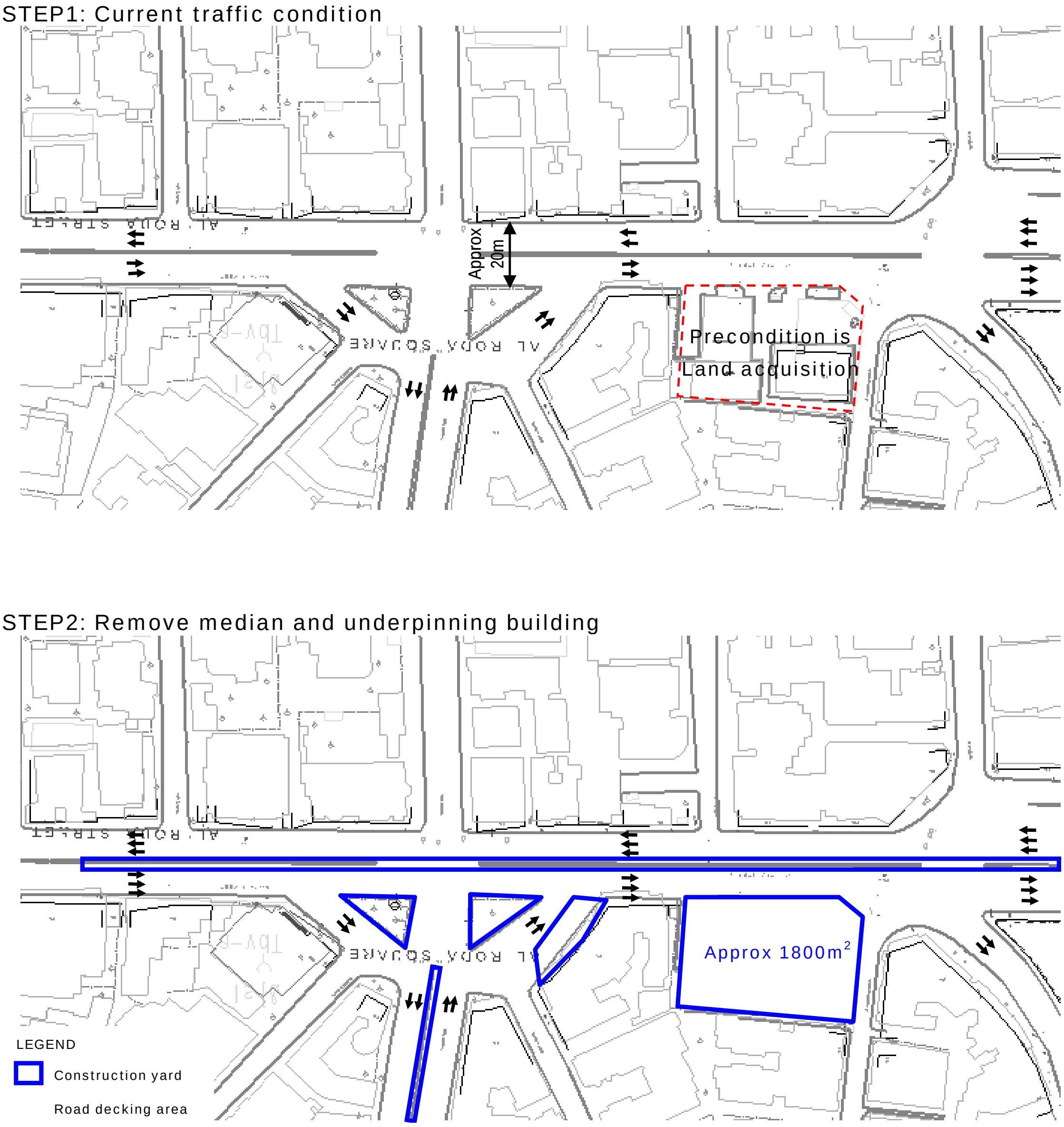


Source: JICA Study Team

Figure 4-232 Procedure 6 to 9 for the Construction of Sta. No. 2: Underpinning Section

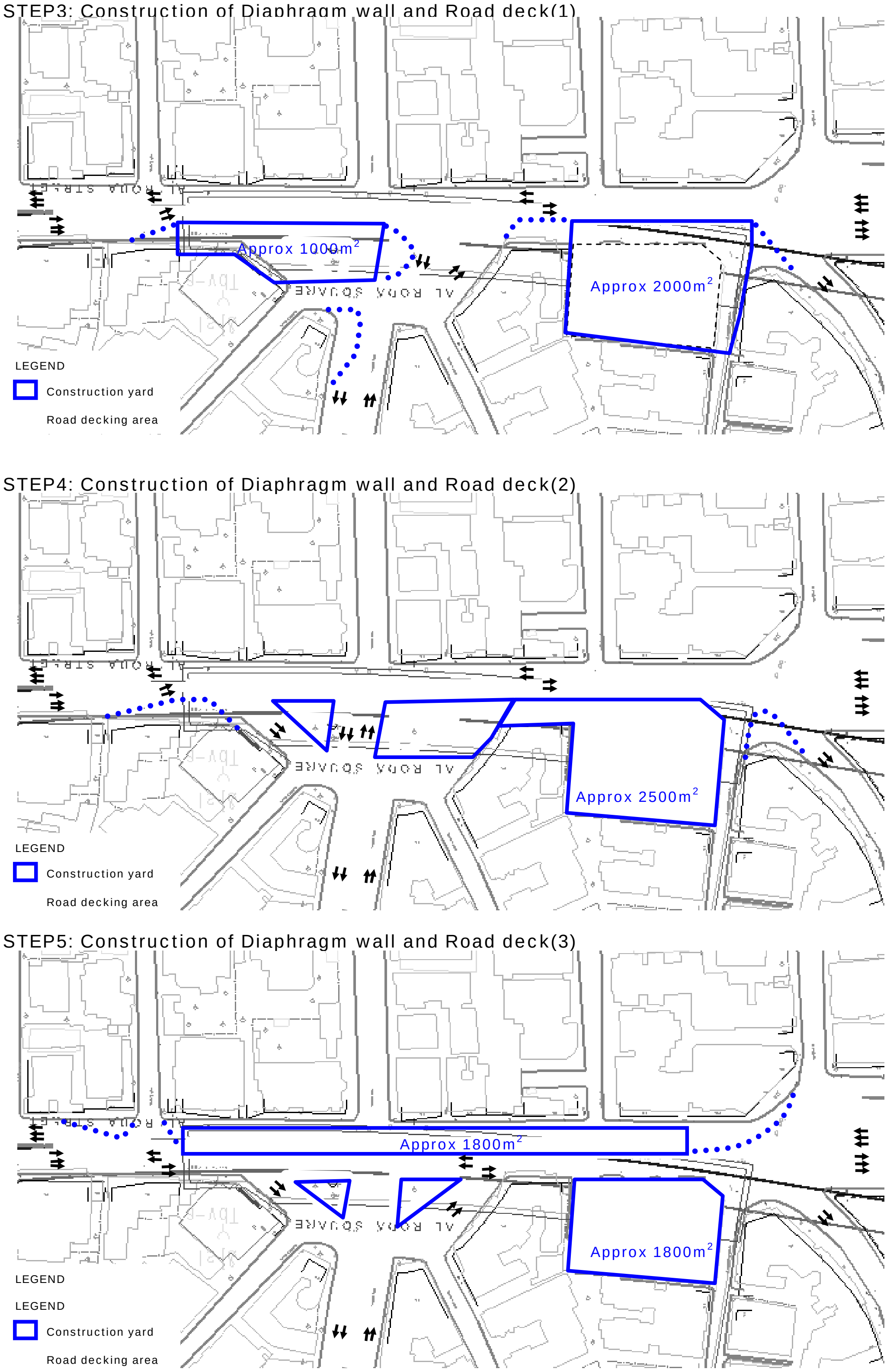
iii) Traffic Management

Conceptual traffic management plan during construction is shown in Figure 4-233 to Figure 4-235.



Source: JICA Study Team

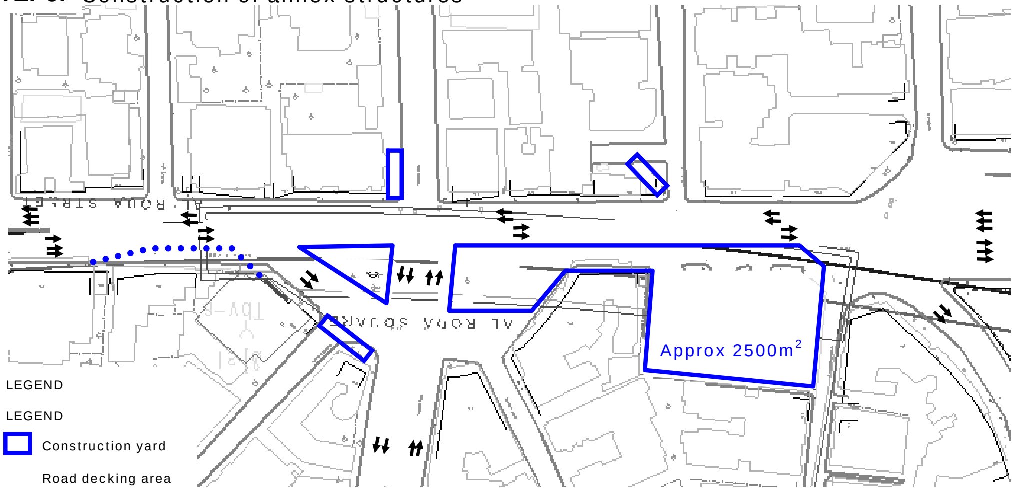
Figure 4-233 Traffic Management Plan during the Implementation of Procedure 1 and 2 for the Construction of Sta. No. 2



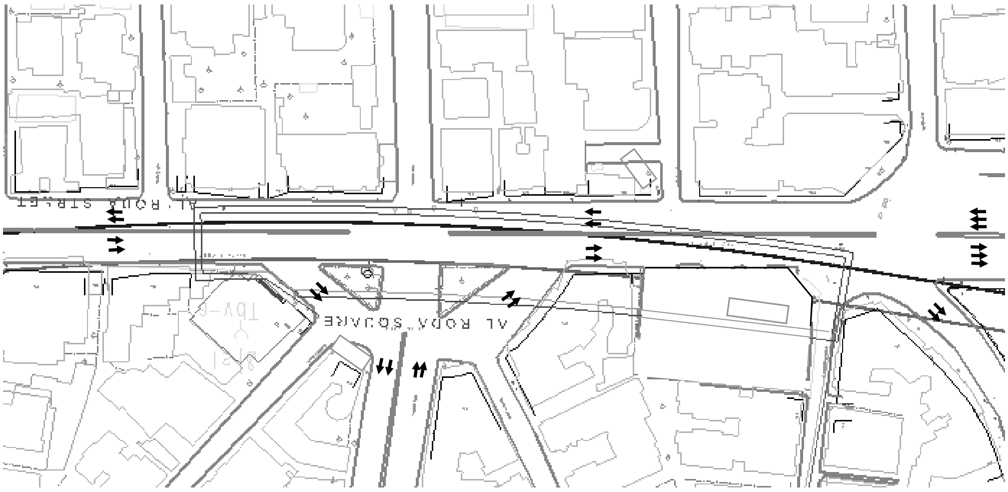
Source: JICA Study Team

Figure 4-234 Traffic Management Plan during the Implementation of Procedure 3 to 5 for the Construction of Sta. No. 2

STEP6: Construction of annex structures



STEP7: Removal road deck, Restoration road and Completion



Source: JICA Study Team

Figure 4-235 Traffic Management Plan during the Implementation of Procedure 6 and 7 for the Construction of Sta. No. 2

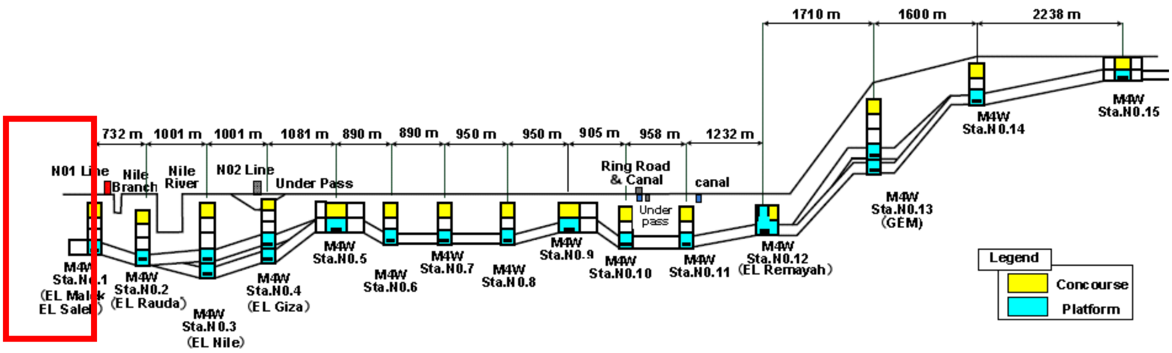
e) Study on Special Construction Method at Complex Location, Sta. No. 1 (El-Malek El-Saleh)

i) Location and Consideration

Considerations for the special construction method are as follows:

- Obstructing buildings (Mosque, Flat1 and Flat2) at Turn Back section
- Construction in the vicinity of underpass, Metro Line1 etc.
- Deep excavation (approx. GL-32m) subject to high water pressure

The longitudinal location is shown in Figure 4-236 while the aerial photograph of the station location is shown in Figure 4-237.



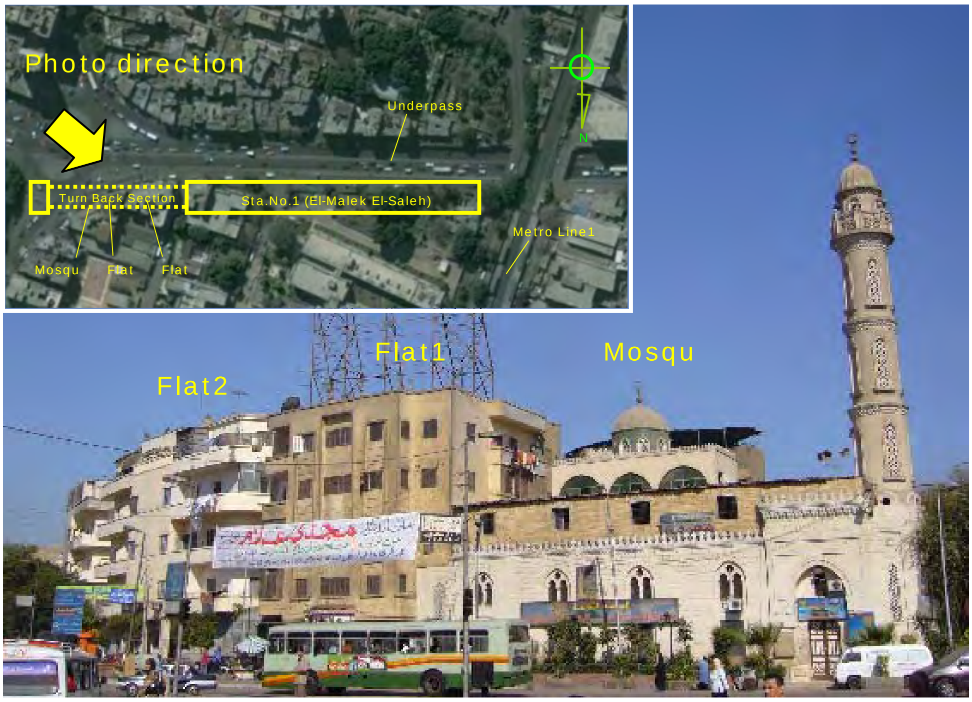
Source: JICA Study Team

Figure 4-236 Complex Location of Sta. No. 1 (El-Malek El-Saleh)

Source: JICA Study Team

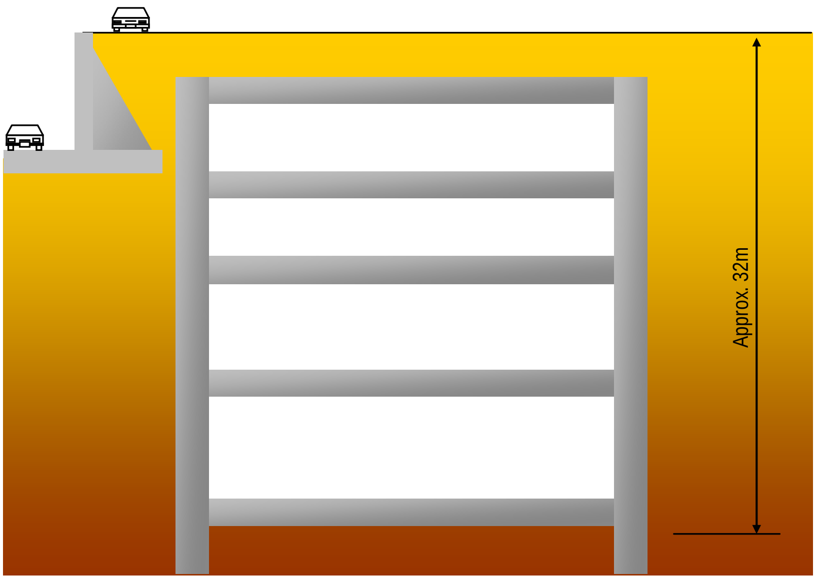
Figure 4-237 Vicinity of Sta.No.1 (El-Malek El-Saleh)

The present situation and cross section is shown in Figure 4-238 and Figure 4-239, respectively.



Source: JICA Study Team

Figure 4-238 Present Situation of Sta. No. 1 (El Malek El Saleh)



Source: JICA Study Team

Figure 4-239 Anticipated Completed Section of Sta. No. 1 (El Malek El Saleh)

ii) Study on Procedure of Construction

Procedure for construction should be studied taking all special considerations into account. Countermeasures for such special consideration are as follows:

Regarding obstructing buildings (Mosqu, Flat 1 and Flat 2) at Turn Back section

The most suitable construction method is studied from the perspective of social impact, constructability and cost of construction and land acquisition. Alternative construction methods to be applied are as follows:

- Cut-and-Cover-Method without Underpinning
- Cut-and-Cover-Method with Underpinning for important structure (Flat)
- Non-Cut-and-Cover Method, Pre-Shell Method
- Non-Cut-and-Cover Method, Multi Face Shield Tunneling Method

Regarding above construction methods, a comparison table is shown in Table 4-74. As described in said table, the non-cut-and-cover method, pre-shell method will be recommended.

Table 4-74 Comparison Table of Tunnel Construction Method for Turn Back Section Behind Sta. No. 1

Construction method	Cut and Cover		Non-Cut and Cover	
	Without underpinning	With underpinning for important structure*)	Pre-shell Method	Multi Face Shield Tunneling Method
Impact to Social environment	Need the land acquisition of 3 buildings crossing station (+)	No need the land acquisition of 3 buildings crrossing station (++)	No need the land acquisition of 3 buildings crossing station (+++)	No need the land acquisition of 3 buildings crossing station (+++)
Constructivity	Nomal cut and cover method (+++)	Cut and cover method with underpinning of 3 buildings (+)	No need underpinning or something like that. (++)	No need underpinning or something like that. (++)
Cost Ratio of construction and land acquisition	Base cost 1.00 (Base) (+++)	Almost same as base cost approx.1.00 (+++)	Almost same as base cost approx.1.00 (+++)	Expensive over.2.00 (+)
Upper construction cost ratio Lower Land acquisition cost ratio	(0.76) (0.24)	(approx. 1.00) (0.00)	(approx. 1.00) (0.00)	(over 2.00) (0.00)
Total Evaluation	Good	Good	Excellent	Fair

Note: Evaluation= Good <-- +++ , ++ , + --> Poor
*) Important structure is flat or Mosqu.

Source: JICA Study Team

Non-Cut-and-Cover Method, Pre-Shell Method

Pre-shell method is shown and described in Figure 4-227 of the preceding section.

Non-Cut-and-Cover Method, Multi Face Shield Tunnelling Method

Multi face shield tunnelling method is shown and described in Figure 4-228 of the preceding section.

<u>Regarding construction in the vicinity of underpass, Metro Line1 etc.</u>

- Observation method with movement sensor

<u>Deep excavation subject to high water pressure</u>

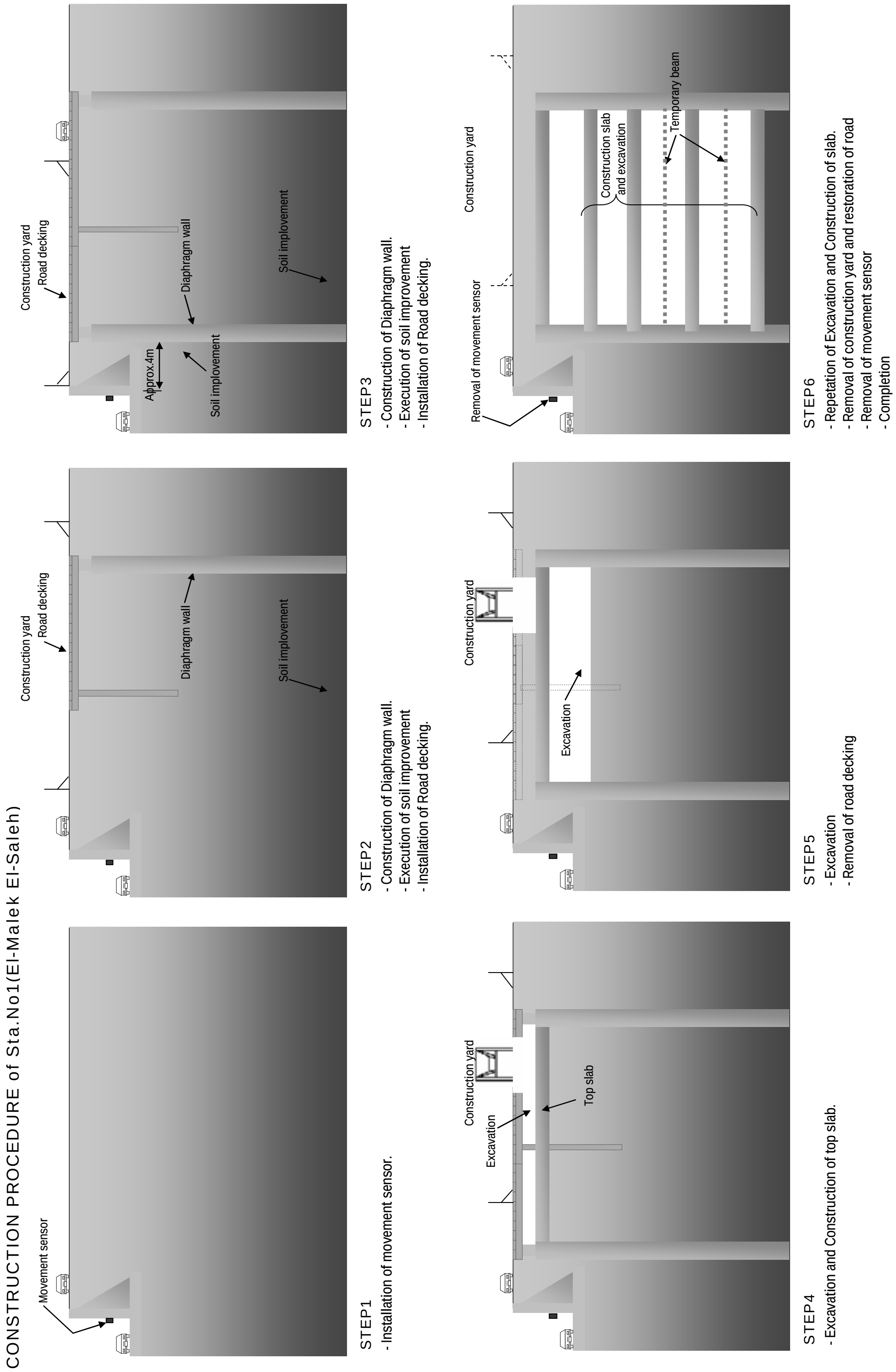
- Soil improvement of embedded section of diaphragm wall prior to deep excavation.
  - Column-Jet Grout Method is recommended as the most suitable soil improvement method for embed section considering the following:
    - ✧ Depth of soil improvement is deeper than GL-35 m.
    - ✧ Soil improvement should be effective for a period longer than approximately two years.
    - ✧ Deformation of ground should be reduced as much as possible.

Table 4-75 Comparison Table of Soil Improvement Method for the Embed Section of the Diaphragm Wall of Sta. No. 1

	Chemical Grouting Method	**Jet Grouting Method**	**Column-Jet Grouting Method**
Applicable Depth	Normally less than approx 30m.	Normally less than approx.30m	Normally less than approx. 60m
Period of improved effective	Comparatively short	Comparatively long	Comparatively long
Improved strength	Comparatively low	Comparatively high	Comparatively high
Evaluation	Bad	Fair	Excellent

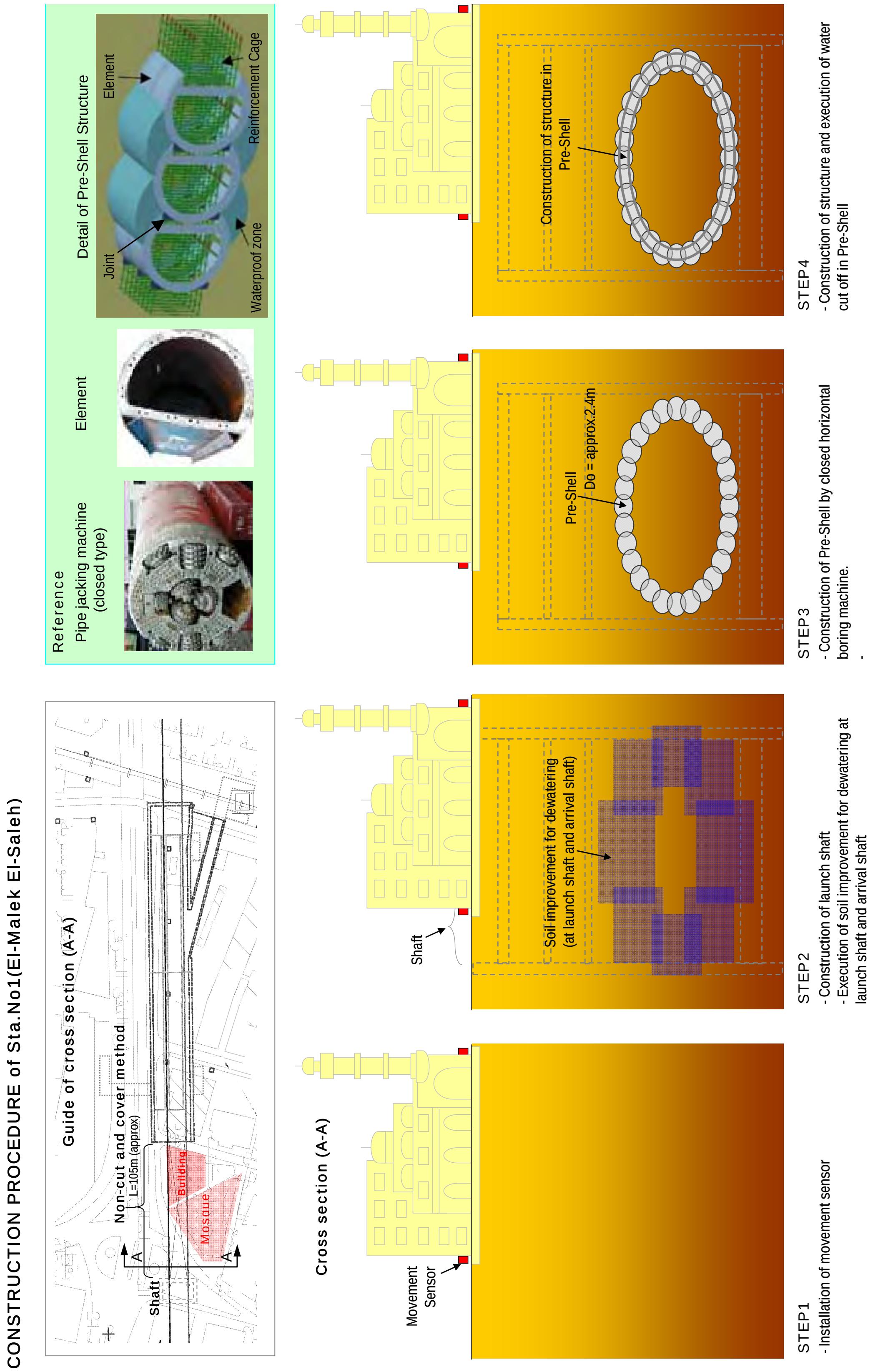
Considering above, the procedure for construction is shown in Figure 4-240.

Additionally, the procedure for the construction of turn back section behind Sta.No.1 is shown in Figure 4-241 and Figure 4-242.



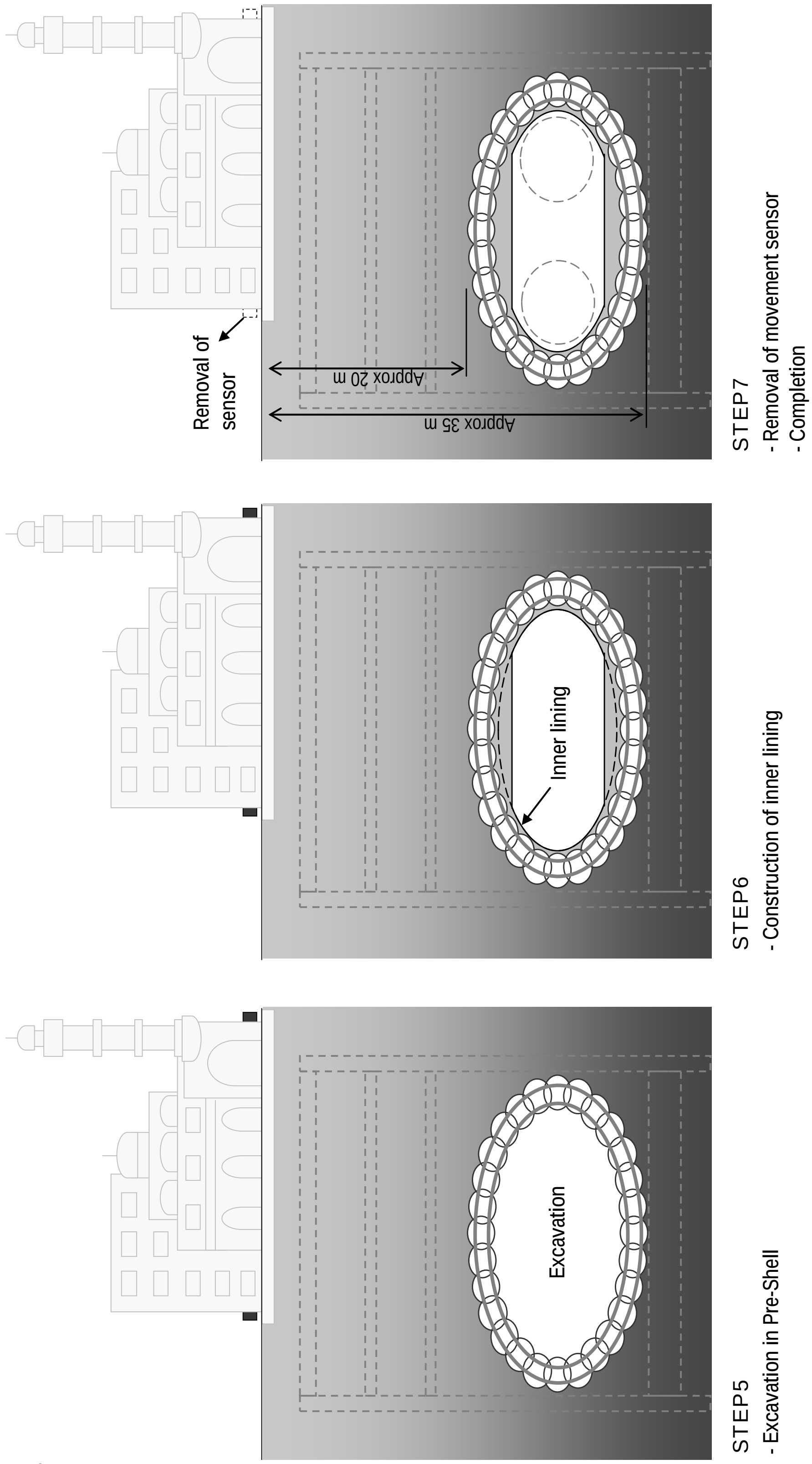
Source: JICA Study Team

Figure 4-240 Procedure for Construction of Sta. No. 1



Source: JICA Study Team

Figure 4-241 Procedure 1 to 4 for the Construction of Sta. No. 1: Turn Back Section Behind



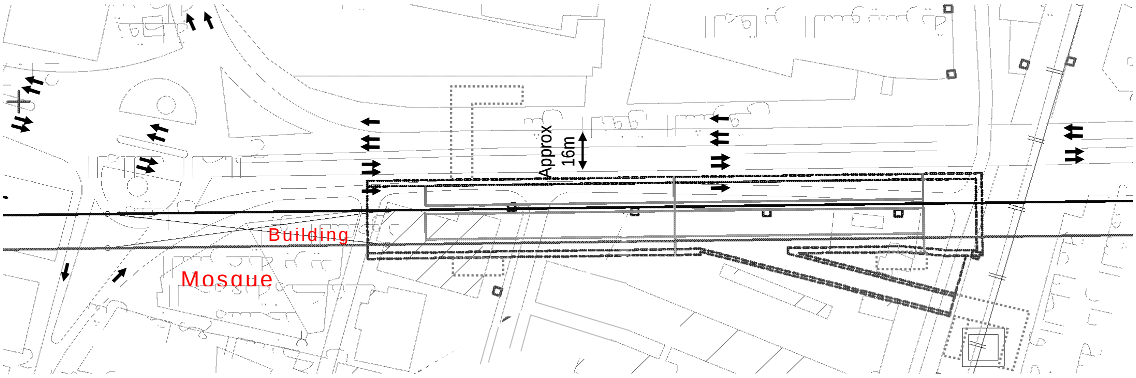
Source: JICA Study Team

Figure 4-242 Procedure 5 to 7 for the Construction of Sta. No. 1: Turn Back Section Behind

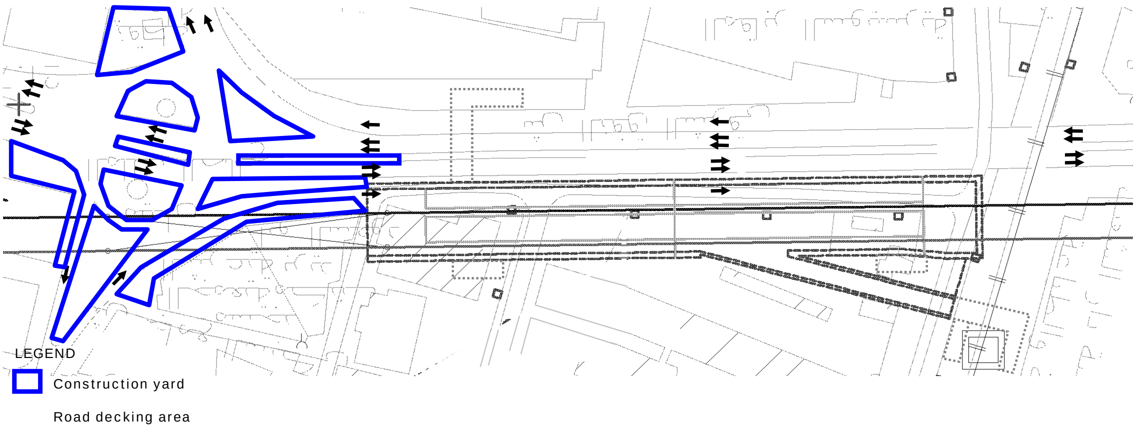
iii) Traffic Management

Conceptual traffic management plan during construction is shown in Figure 4-243 to Figure 4-245.

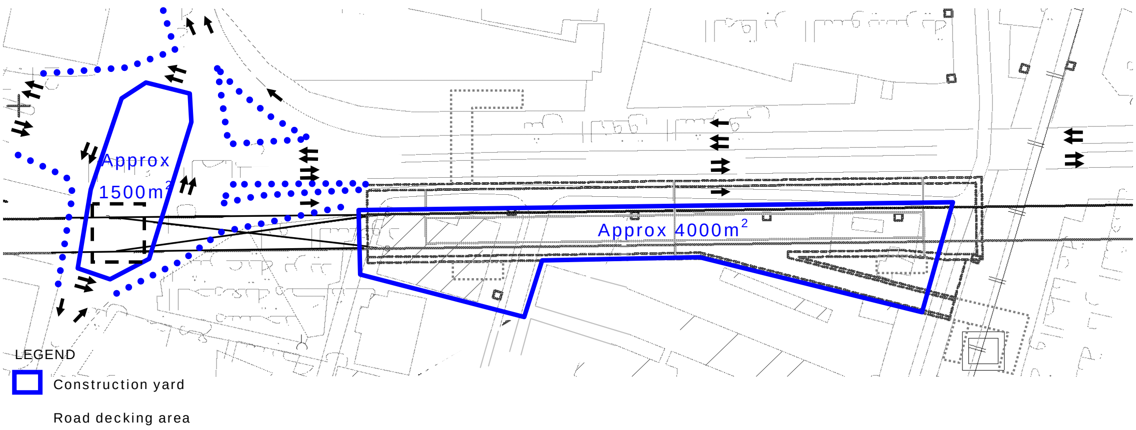
STEP1: Current traffic condition



STEP2: Removal of median



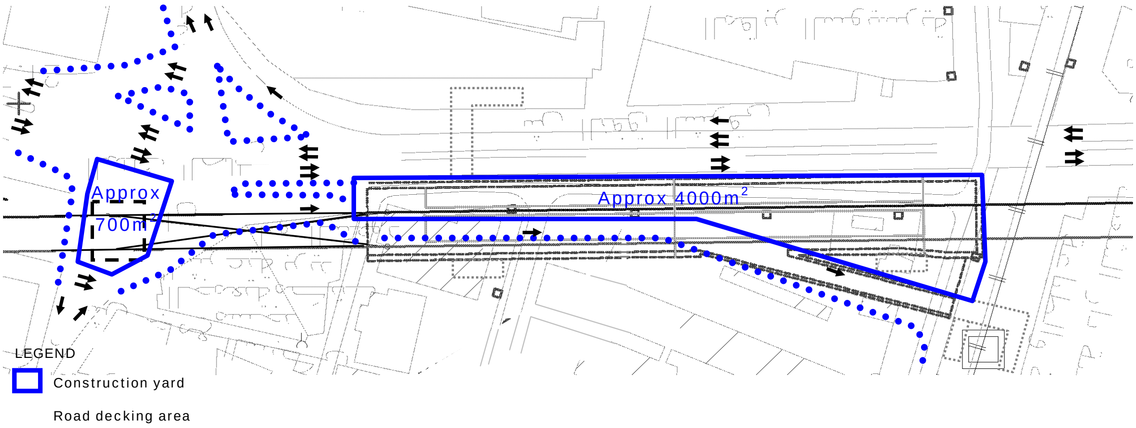
STEP3: Construction of Diaphragm wall and installation of road deck(1)



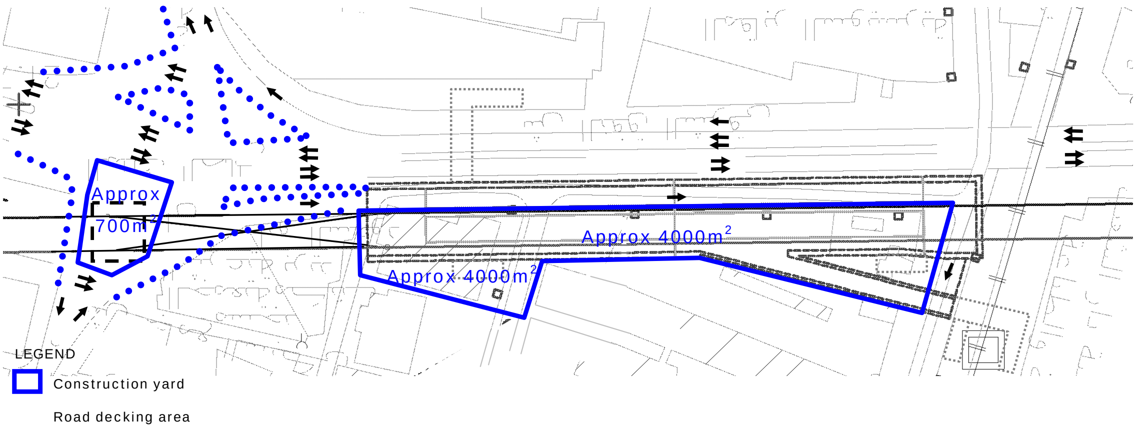
Source: JICA Study Team

Figure 4-243 Traffic Management Plan during Implementation of Procedure 1 to 3 for the Construction of Sta. No. 1

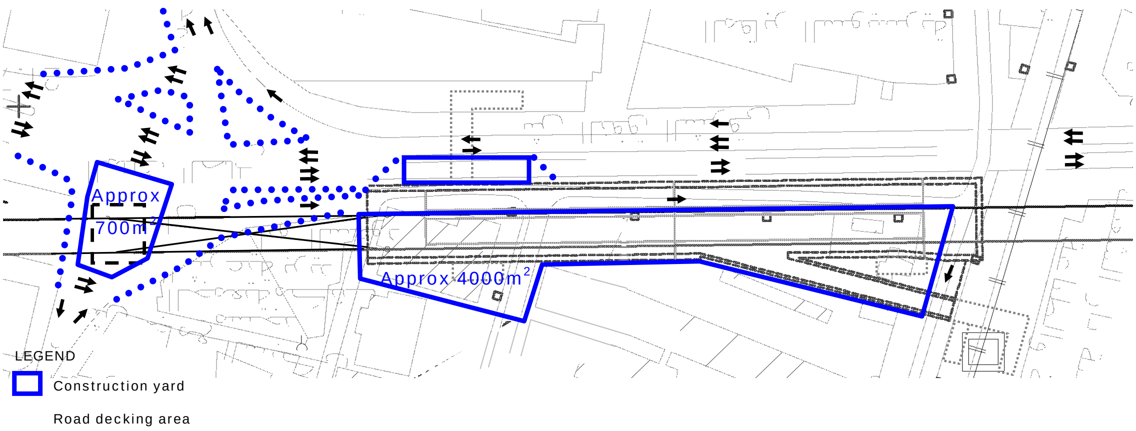
STEP4: Construction of Diaphragm wall and installation of road deck(2)



STEP5: Excavation, Construction slab and Construction of PreShell



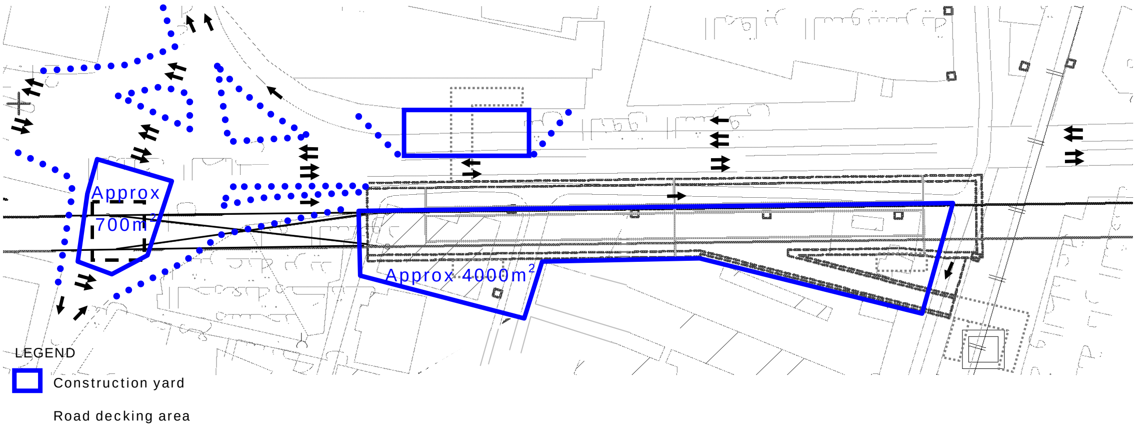
STEP6: Construction of annex structures(1)



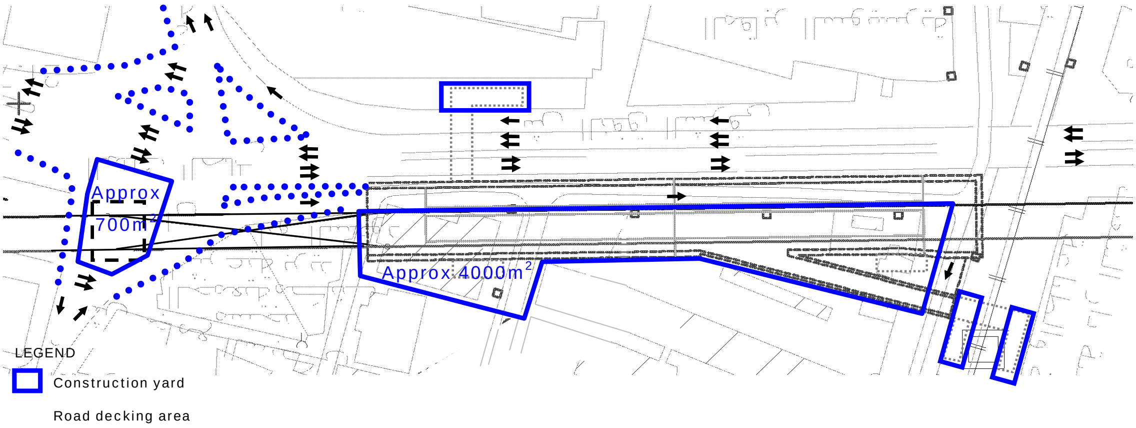
Source: JICA Study Team

Figure 4-244 Traffic Management Plan during the Implementation of Procedure 4 to 6 for the Construction of Sta. No. 1

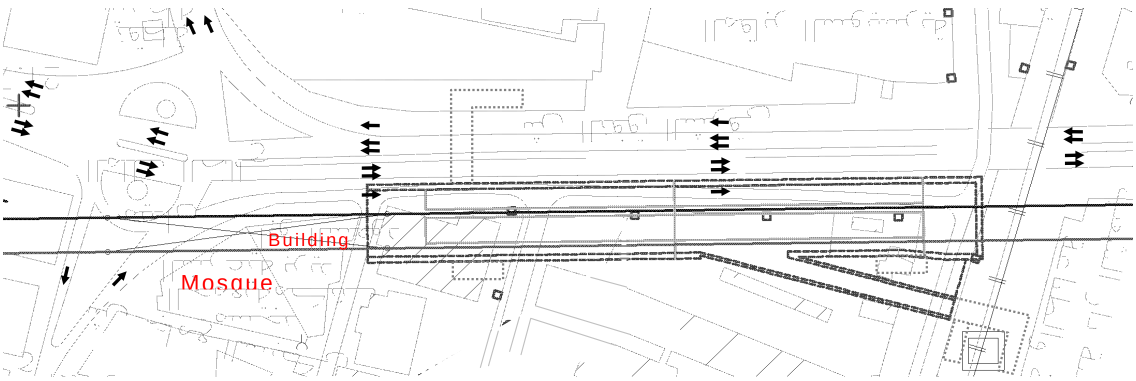
STEP7: Construction of annex structures(2)



STEP8: Construction of annex structures(3)



STEP9: Removal of road deck, Restoration of road and



Source: JICA Study Team

Figure 4-245 Traffic Management Plan during the Implementation of Procedure 7 to 9 for the Construction of Sta. No. 1

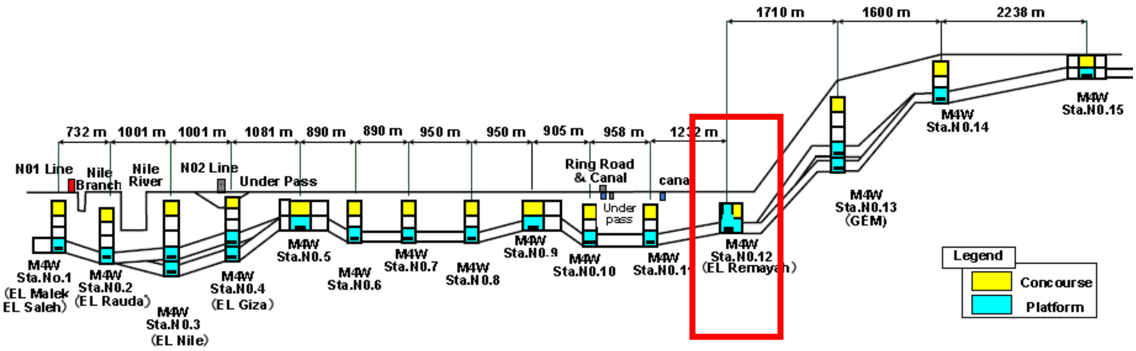
f) Study on Special Construction Method, Sta. No. 12

i) Location and Consideration

Consideration for the special construction method is as follows,

- Construction on the traffic at the vicinity of El Remayah Square

The longitudinal location is shown in Figure 4-246 while the aerial photo of the station location is shown in Figure 4-247.



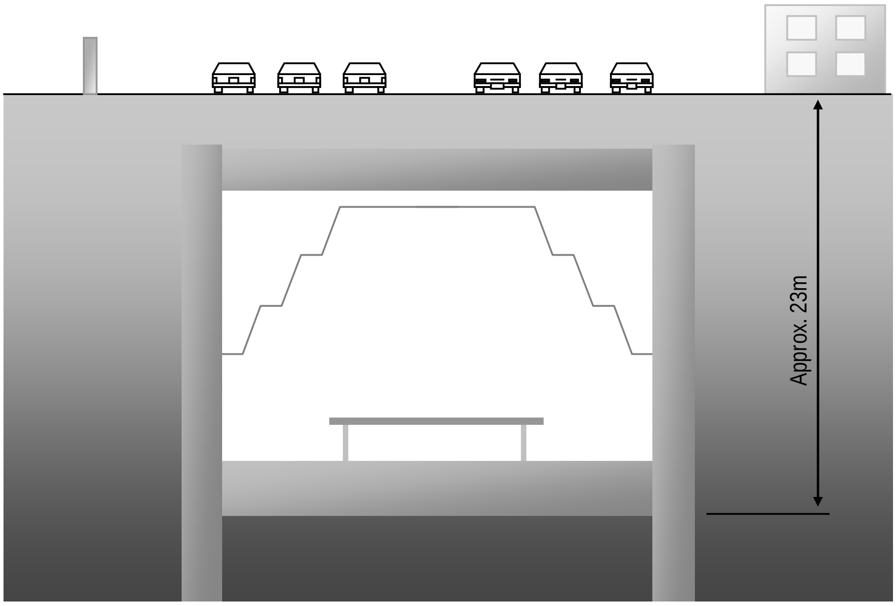
Source: JICA Study Team

Figure 4-246 Location of Sta. No. 12 (El Remayah)

Source: JICA Study Team

Figure 4-247 Vicinity of Sta. No. 12 (El Remayah)

The cross section of Sta. No. 12 is shown in Figure 4-248.



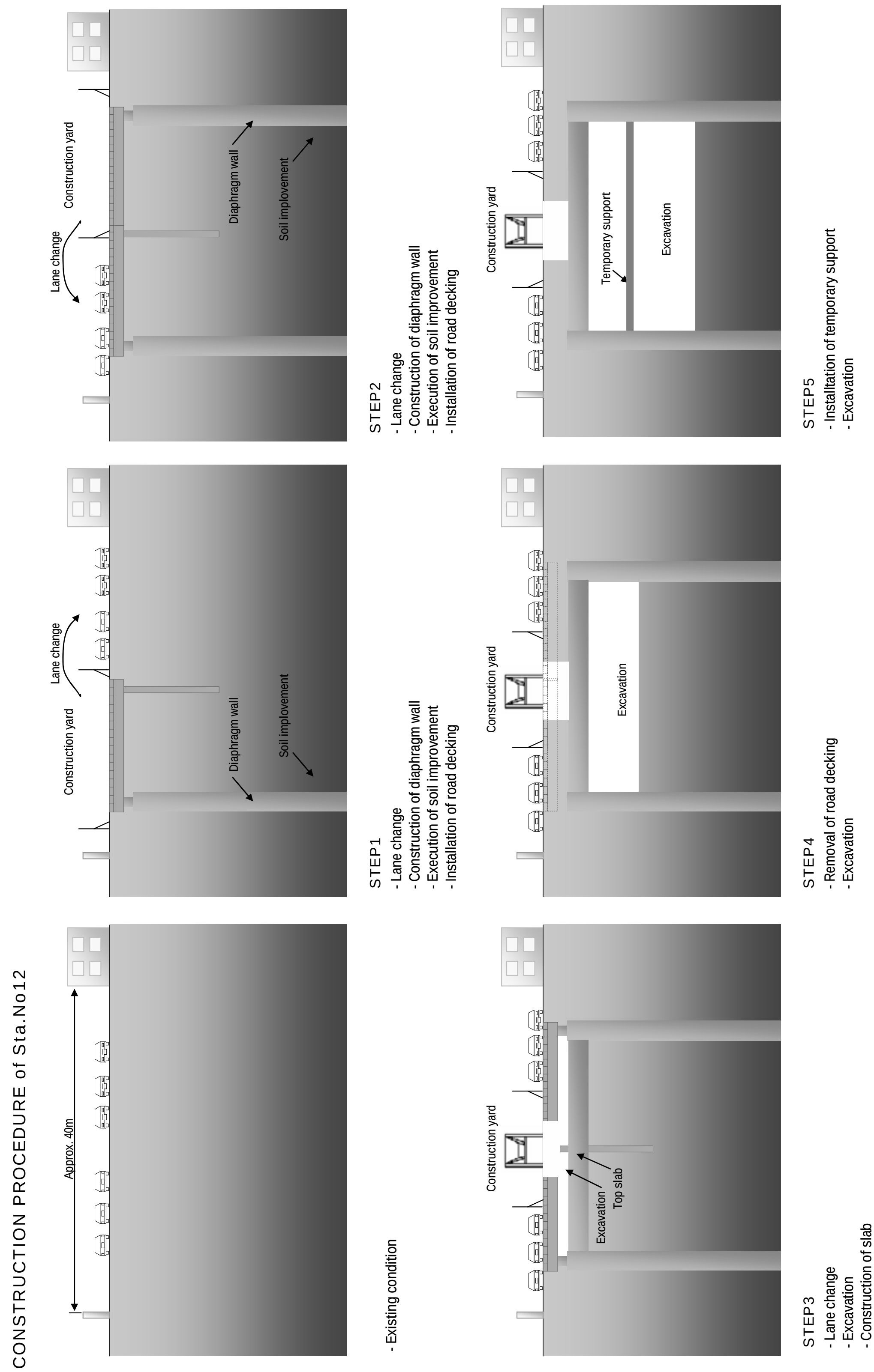
Source: JICA Study Team

Figure 4-248 Anticipated Completed Section of Sta. No. 12 (El Remayah)

ii) Study on the Procedure for Construction

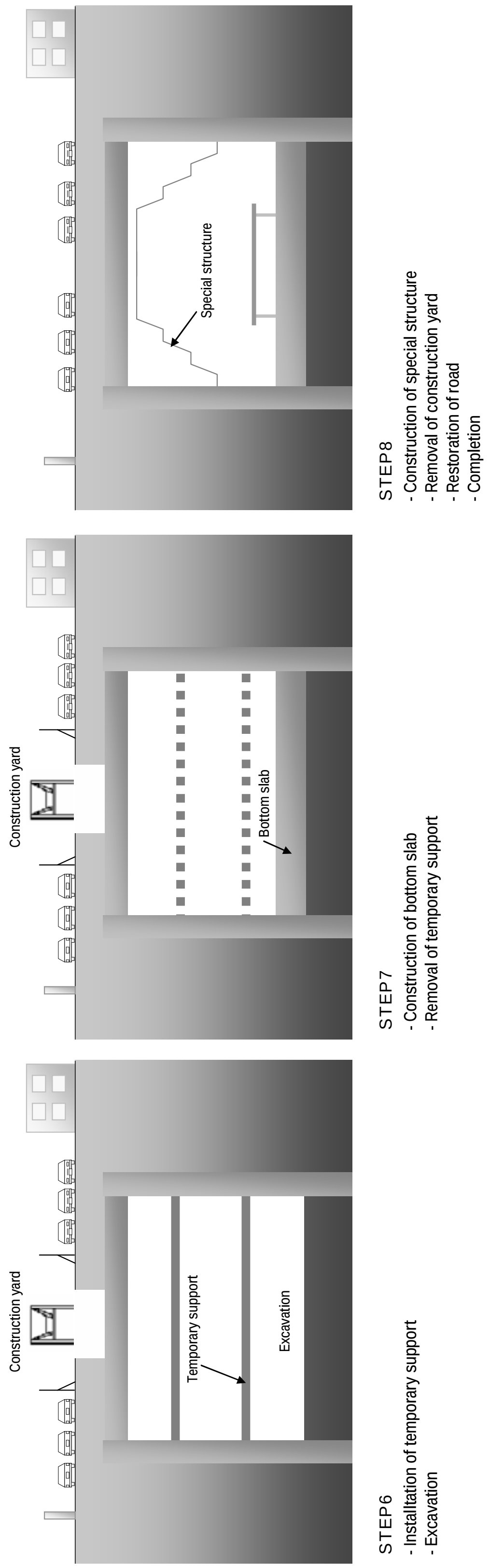
Procedure for construction should be studied taking full conditions into account. The countermeasure for such special consideration is to adopt the road deck method for the construction in the vicinity of El Remayah Square.

Considering above, the procedure for construction is shown in Figure 4-249 and Figure 4-250.



Source: JICA Study Team

Figure 4-249   Procedure 1 to 5 for the Construction of Sta. No. 12 (El-Remayah)

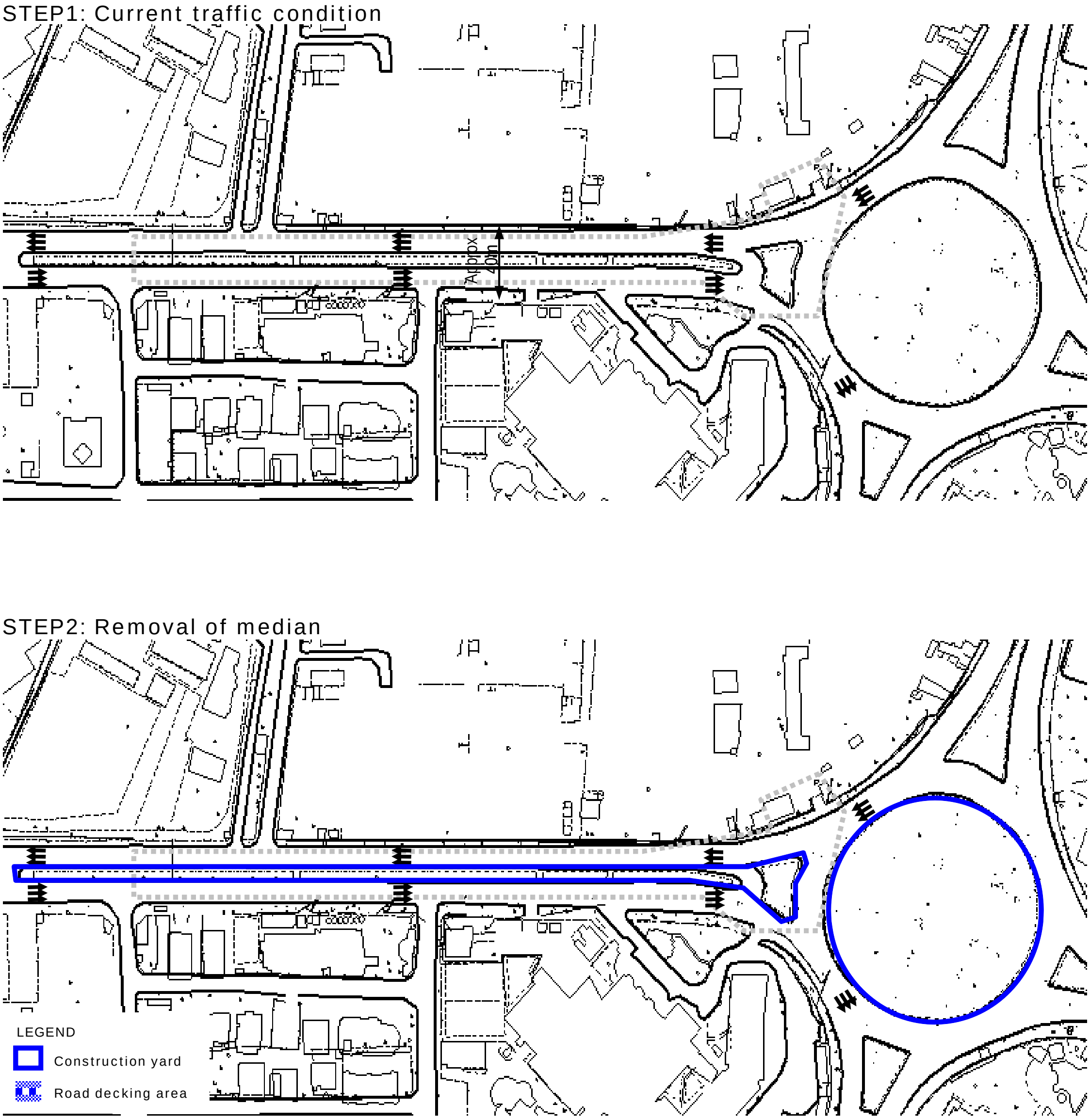


Source: JICA Study Team

Figure 4-250 Procedure 6 to 8 for the Construction of Sta. No. 12 (El Remayah)

iii) Traffic Management

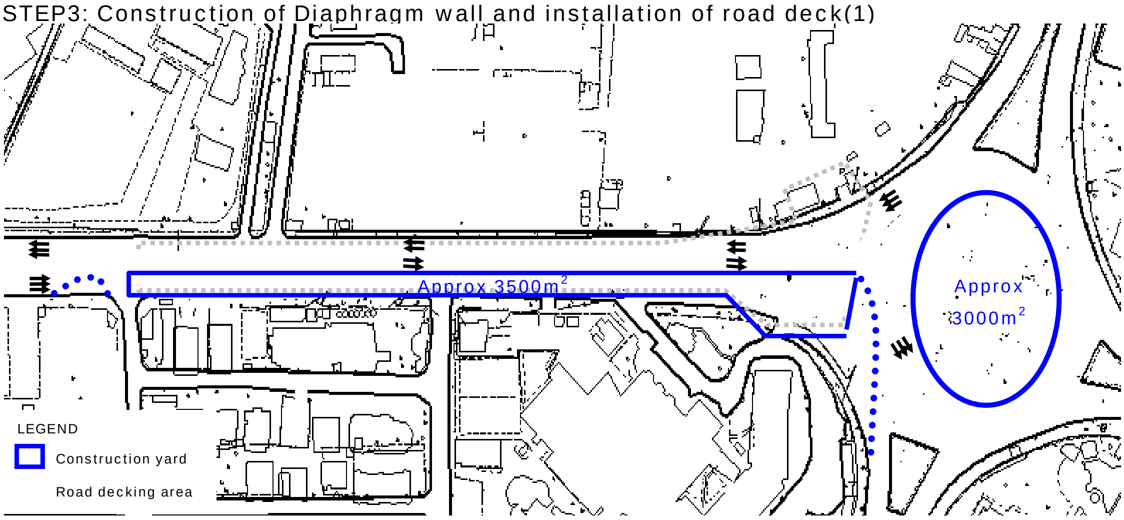
Conceptual traffic management plan during the construction is shown in Figure 4-249 to Figure 4-253.



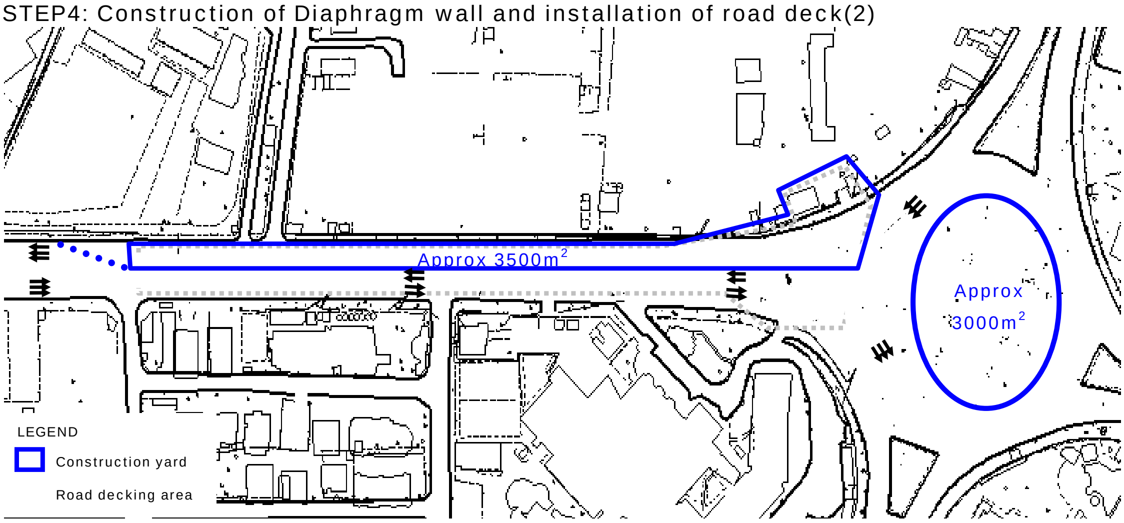
Source: JICA Study Team

Figure 4-251 Traffic Management Plan during the Implementation of Procedure 1 and 2 for the Construction of Sta. No. 12

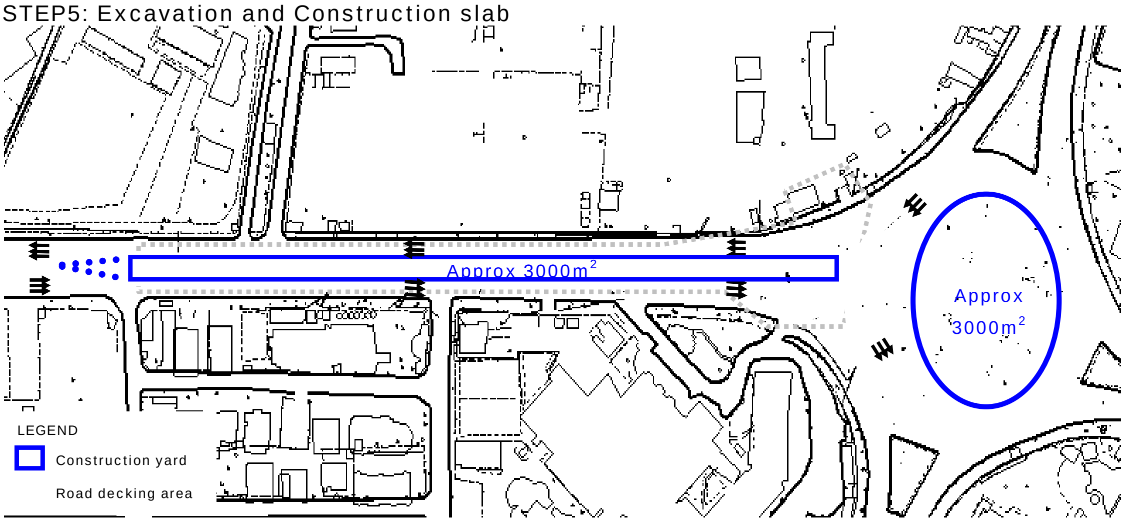
STEP3: Construction of Diaphragm wall and installation of road deck(1)



STEP4: Construction of Diaphragm wall and installation of road deck(2)



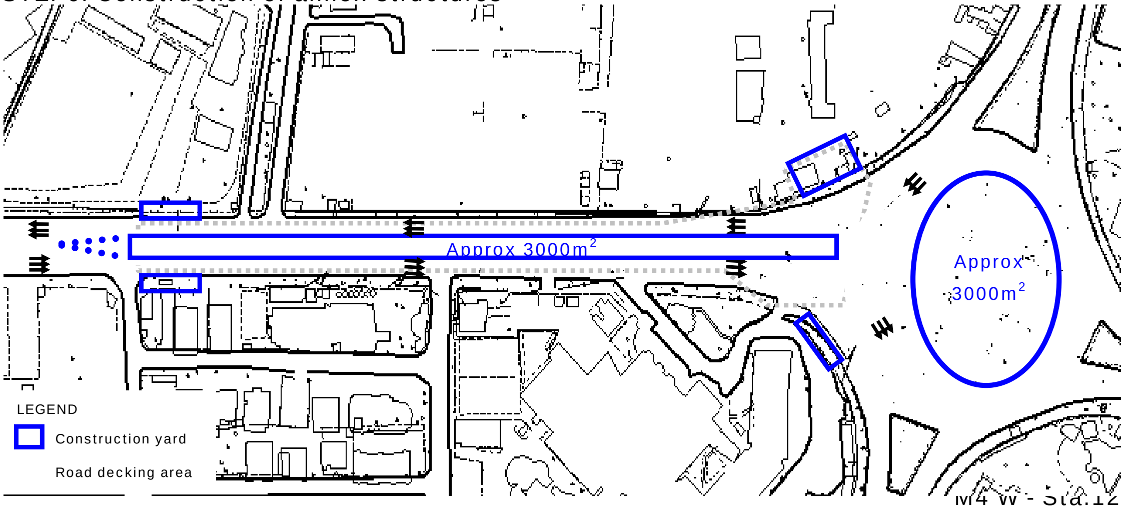
STEP5: Excavation and Construction slab



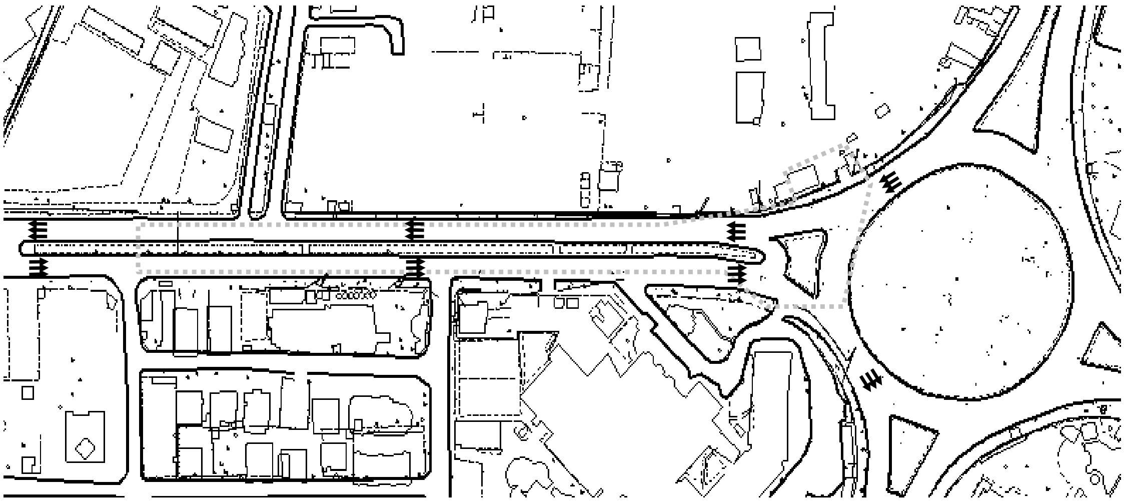
Source: JICA Study Team

Figure 4-252 Traffic Management Plan during the Implementation of Procedure 3 to 5 for the Construction of Sta. No. 12

STEP6: Construction of annex structures



STEP7: Removal of road deck, Restoration of road and Completion



Source: JICA Study Team

Figure 4-253 Traffic Management Plan during the Implementation of Procedure 6 and 7 for the Construction of Sta. No. 12

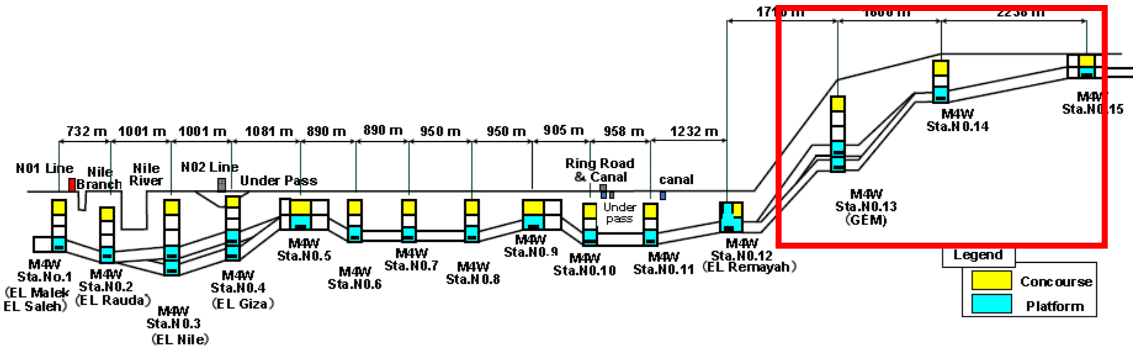
g) Study on the Special Construction Method, Sta. Nos. 13-15

i) Location and Consideration

Considerations for the special construction method are as follows:

- Construction in a suburban area
- Construction on the slope (Sta.No.13)
- Deep excavation (Sta.No.13)

The longitudinal location is shown in Figure 4-254 while the aerial photo of stations' location is shown in Figure 4-255.



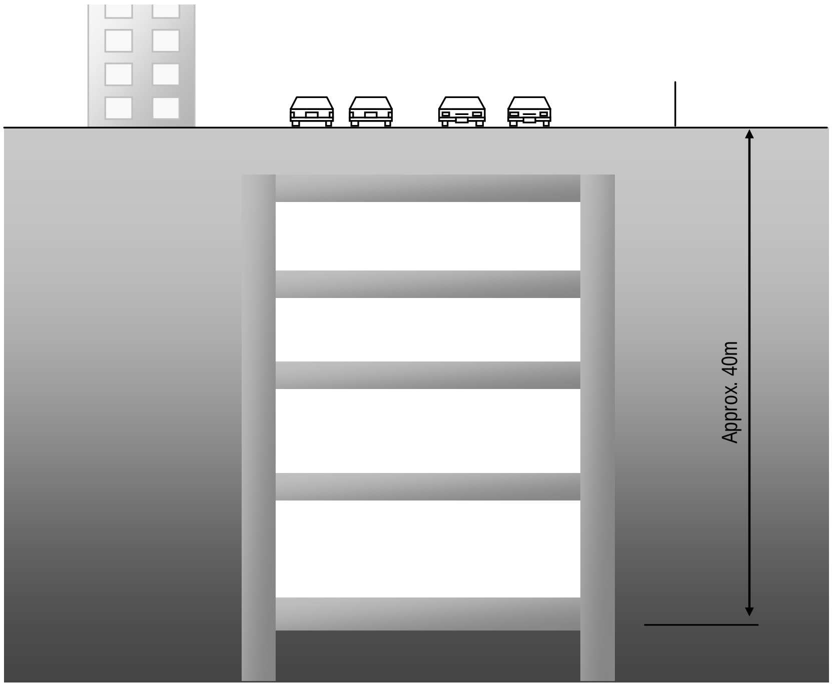
Source: JICA Study Team

Figure 4-254 Location of Sta. Nos. 13-15

Source: JICA Study Team

Figure 4-255 Vicinity at Sta. Nos. 13-15

Cross section of Sta.No.13 shown in Figure 4-256 is typical to Station Nos. 14 and 15.



Source: JICA Study Team

Figure 4-256 Anticipated Completed Section of Sta. No. 13

ii) Study on the procedure of construction

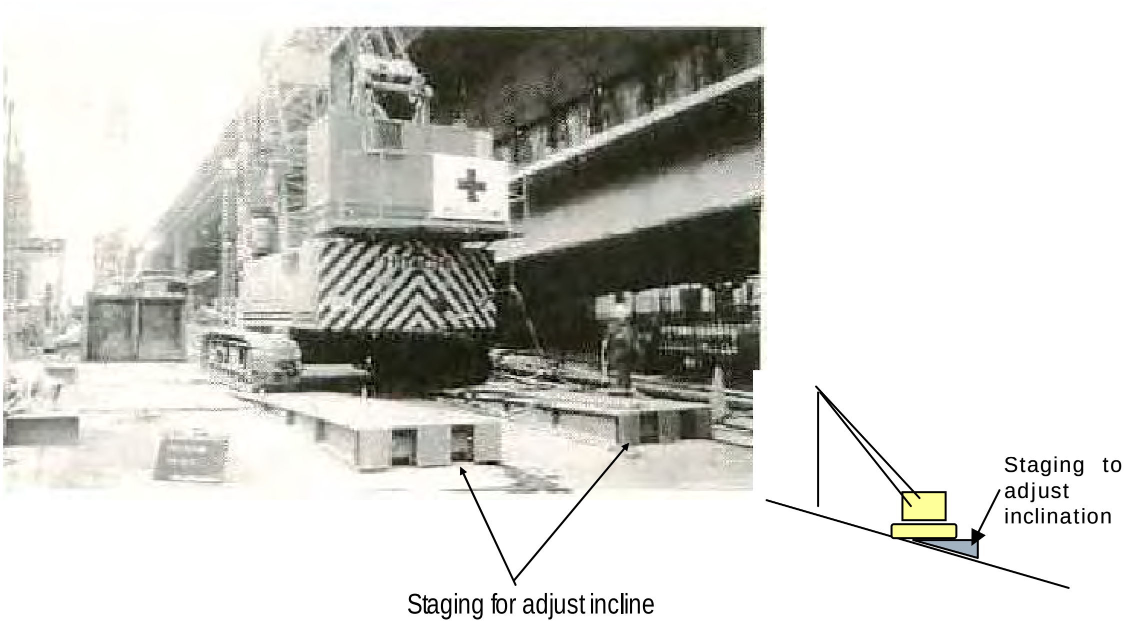
Procedure for construction should be studied taking all considerations into account. Countermeasures for such special considerations are as follows;

Regarding construction in a suburban area

- Initiate simple temporary diversion road for the existing traffic control instead of adopting road decking during construction at Sta.No13 and Sta.No.14
- Neither diversion road nor road decking is required at Sta.No15.

Regarding construction on the slope near Sta.No.13

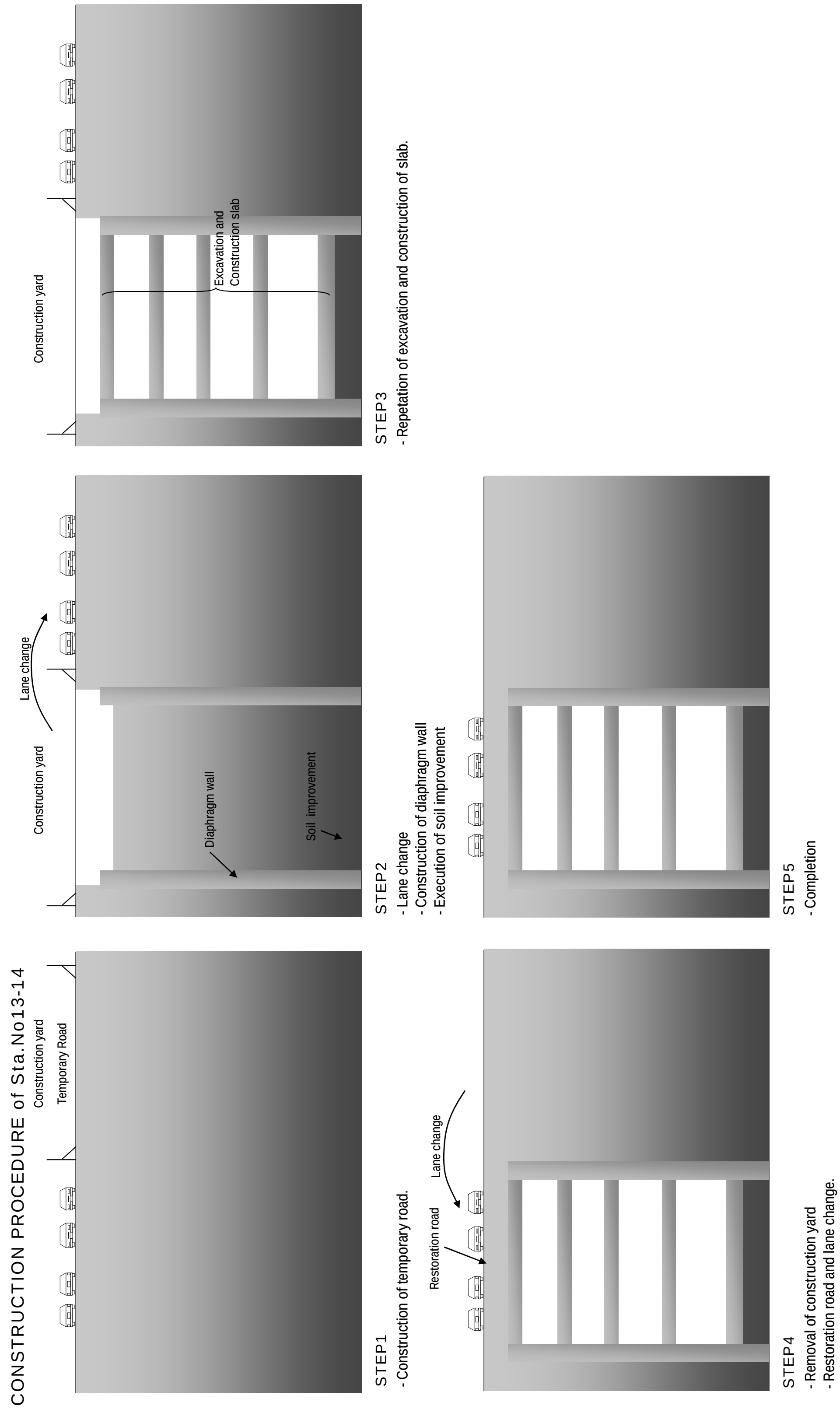
- Provide staging to adjust inclination as shown in Figure 4-257 or other related countermeasures.



Source: JICA Study Team

Figure 4-257 Staging to Adjust Inclination

Considering above, the procedure for construction is shown in Figure 4-258.



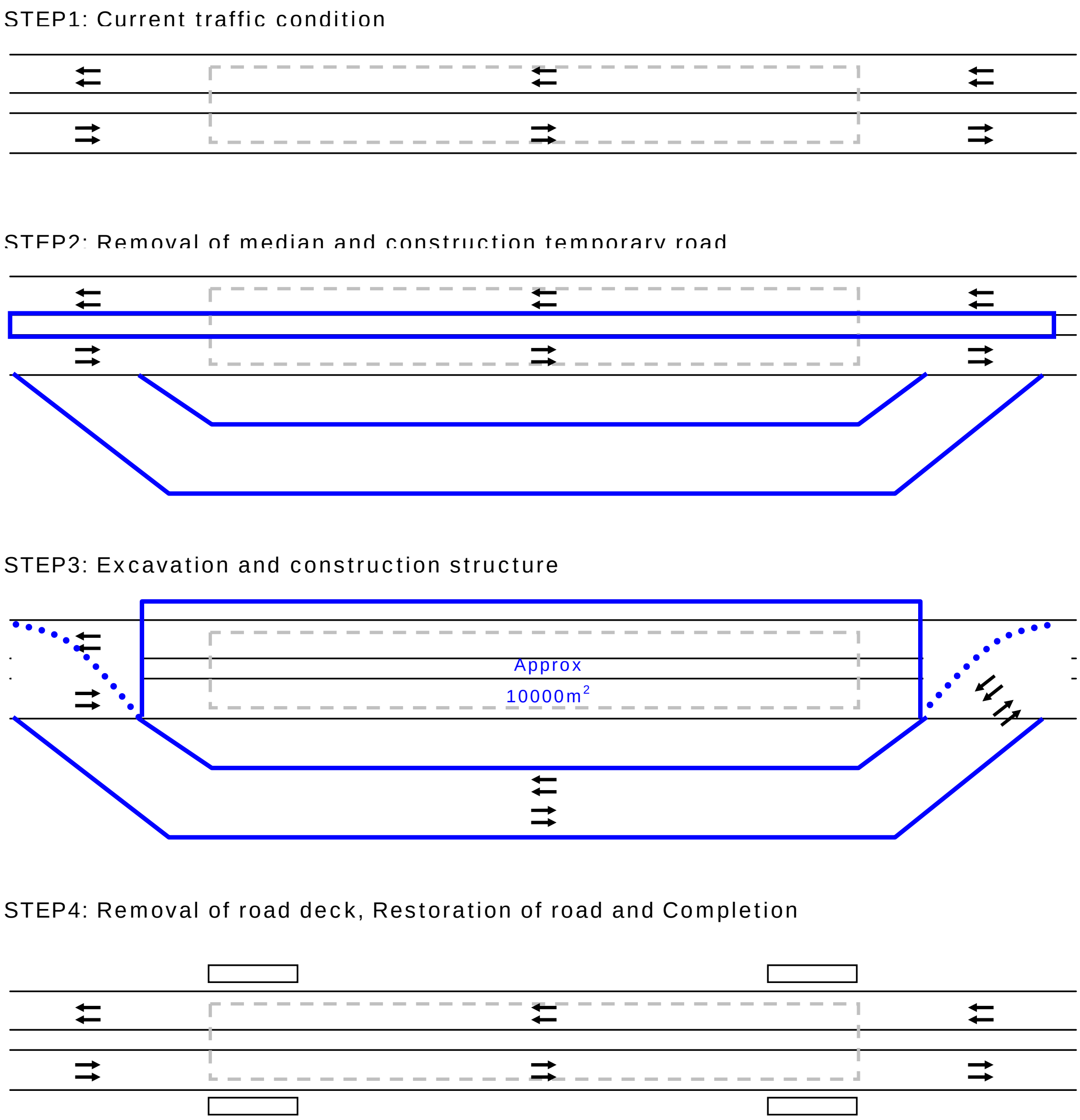
Source: JICA Study Team

Figure 4-258 Procedure for the Construction of Sta. No. 13

iii) Traffic Management

Conceptual traffic management plan during the construction at Sta.No13 and Sta.No.14 is shown in Figure 4-259.

Meanwhile, since Sta. No. 15 will be constructed in an open space, traffic management during its construction will not be required.



Source: JICA Study Team

Figure 4-259 Traffic Management Plan during the Implementation of Procedure fo the Construction of Sta. Nos. 13 and 14

4.7.6 Construction Schedule

(1) General Condition

For the study of the construction schedule, main conditions to be considered are as follows;

- Construction method and procedure as shown in previous sections
- Adopt three work shifts
- Working rate of twenty four days per month

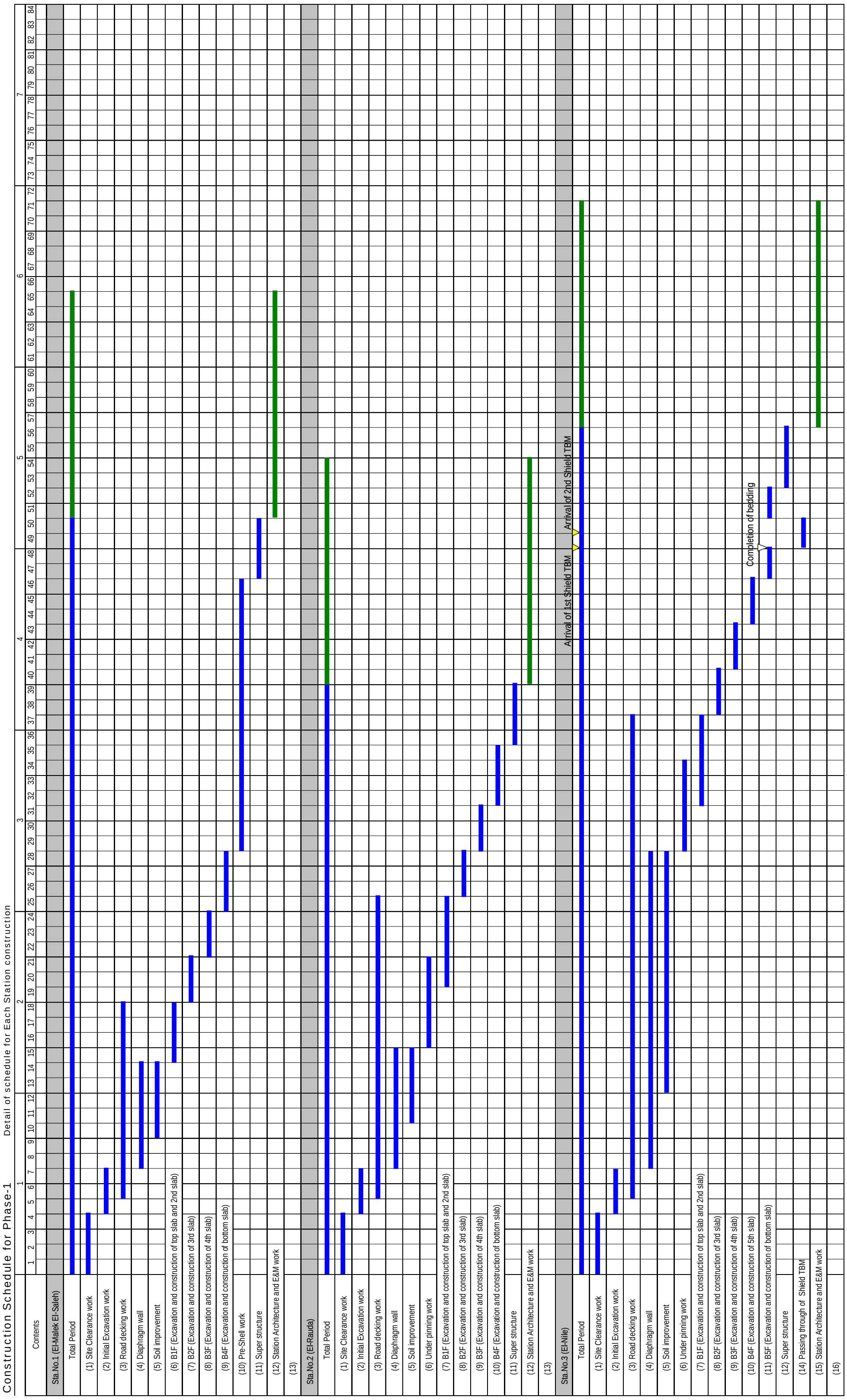
(2) Schedule of Station Construction

Construction schedule chart for each station is shown in Figure 4-260 to Figure 4-262.

Approximate construction period for each station and reasons why some stations require comparatively long construction period are tabulated as follows;

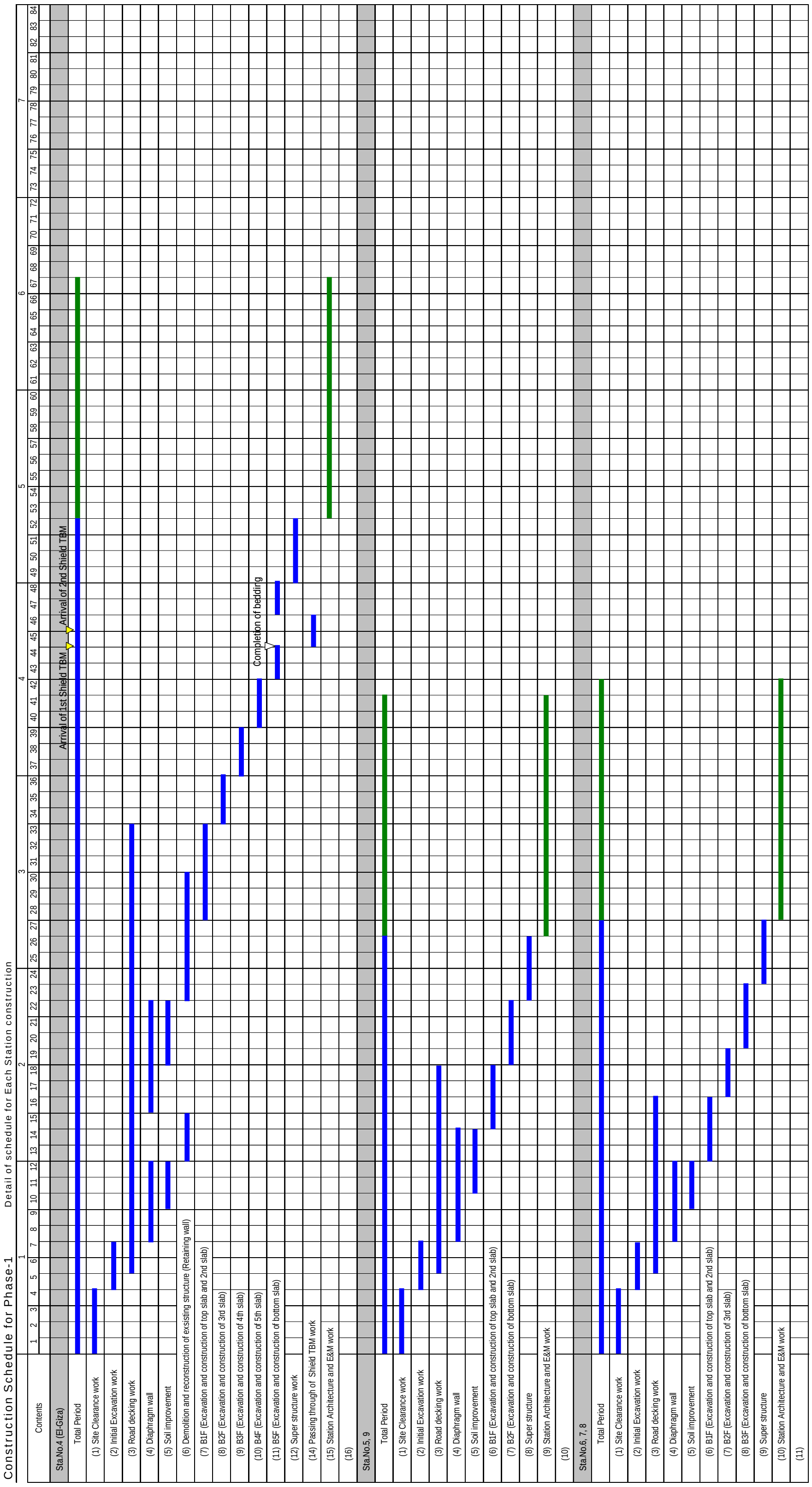
Table 4-76 Summary of Station Construction Period

Name of station	Period approx. (year)	Note (Reason of comparatively long construction period)
Station No.1 (El-Malek El-Saleh)	5	Deep excavation, Underpinning of Building(Pre-Shell Method)
Station No.2 (El-Rauda)	5	Deep excavation, Underpinning of Building
Station No.3 (El-Nile)	6	Deep excavation, Underpinning of Giza Flyover, Narrow yard
Station No.4 (El-Giza)	6	Deep excavation, Demolition and Restration of Underpass
Station No.5	3	
Station No.6	4	
Station No.7	4	
Station No.8	4	
Station No.9	3	
Station No.10	3	
Station No.11	4	
Station No.12 (El-Rauda)	4	
Station No.13	3	
Station No.14	3	
Station No.15	3	



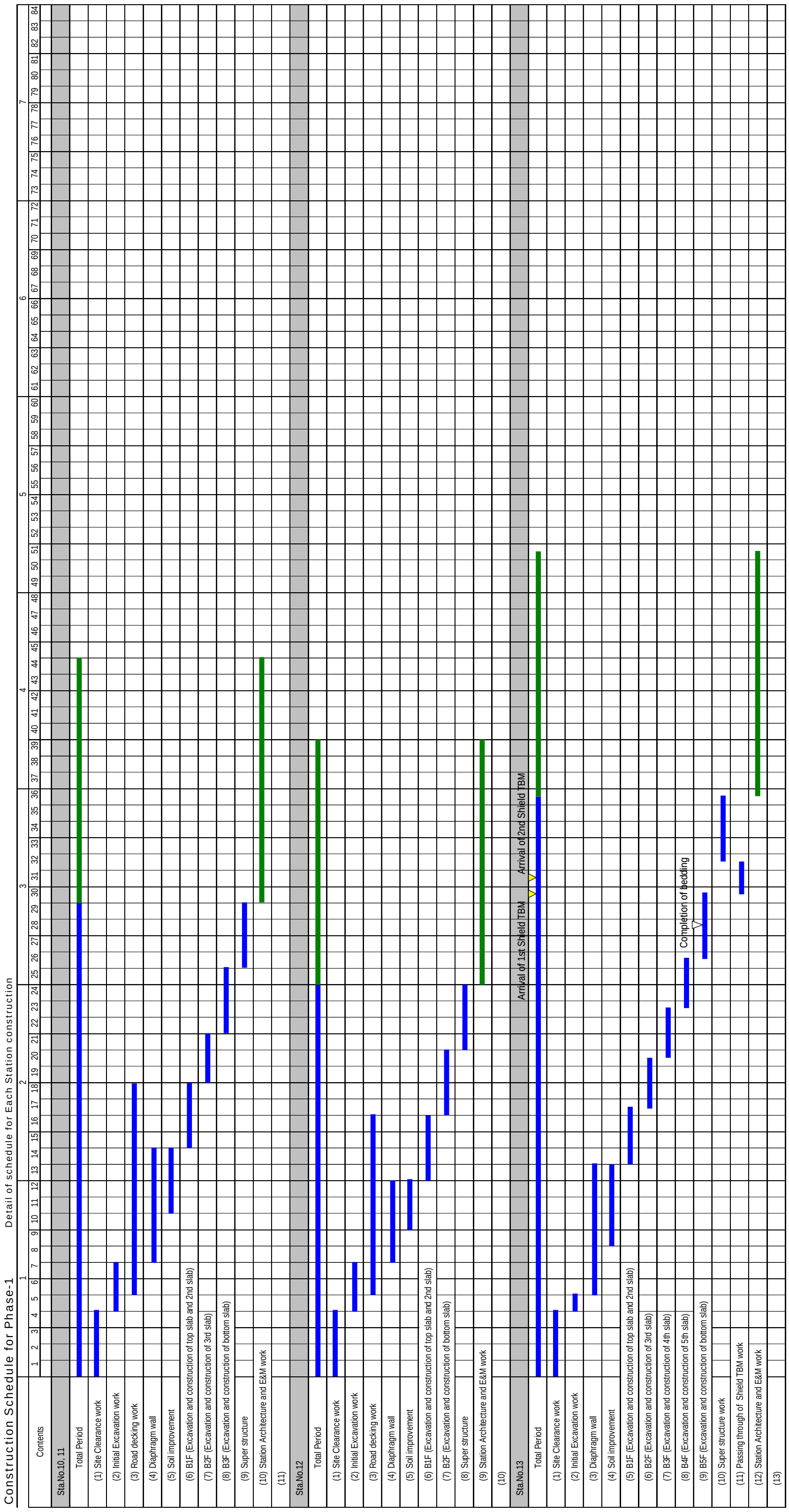
Source: JICA Study Team

Figure 4-260 Detailed Schedule for the Construction of Sta. Nos. 1 to 3



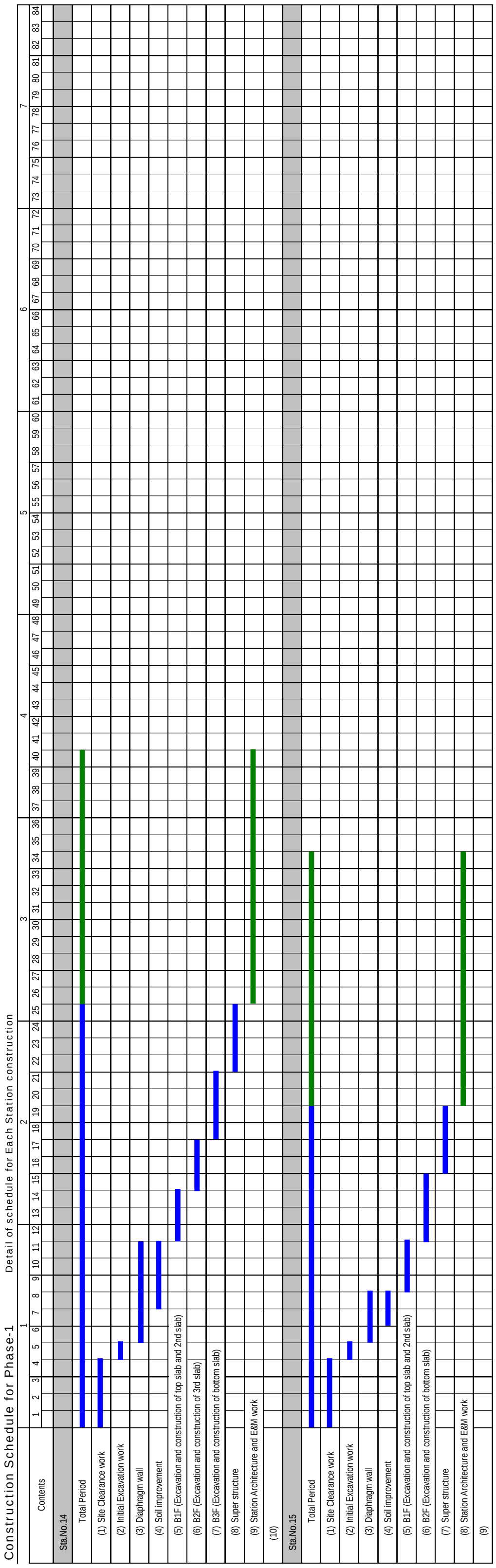
Source: JICA Study Team

Figure 4-261 Detailed Schedule for the Construction of Sta. Nos. 4 to 9



Source: JICA Study Team

Figure 4-262 Detailed Schedule for the Construction of Sta. Nos. 10 to 13



Source: JICA Study Team

Figure 4-263 Detailed Schedule for the Construction of Sta. Nos. 14 and 15

(3) Schedule of Tunnel Construction

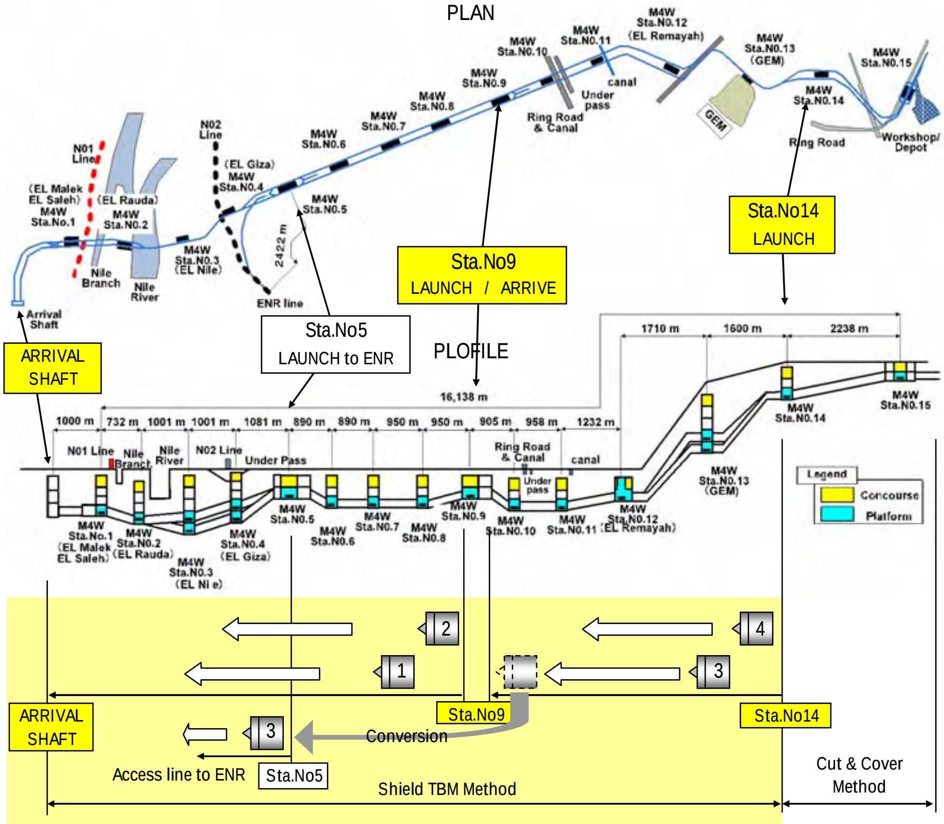
a) Shield TBM Driving Parameter

Taking into consideration the existence of collapsible sand with low uniformity coefficient in Cairo, shield TBM driving parameters based on the practices in Japan are shown as follows:

- Main Driving Speed: 360 m/month (=15 m/day *24 days/1 month)
- Initial Driving Speed: 180 m/month (=7.5 m/day*24 days/1 month)
- Arrival Driving Speed: 216 m/month (=9 m/day*24 days/1 month)
- Period of Launching Work (approximately 0.5 month)
- Period of Passing through Station and Launching Work (approximately 1 month)

b) Construction Plan of Shield Tunnel

Construction plan of Shield Tunnel studied in previous section is shown in Figure 4-264.

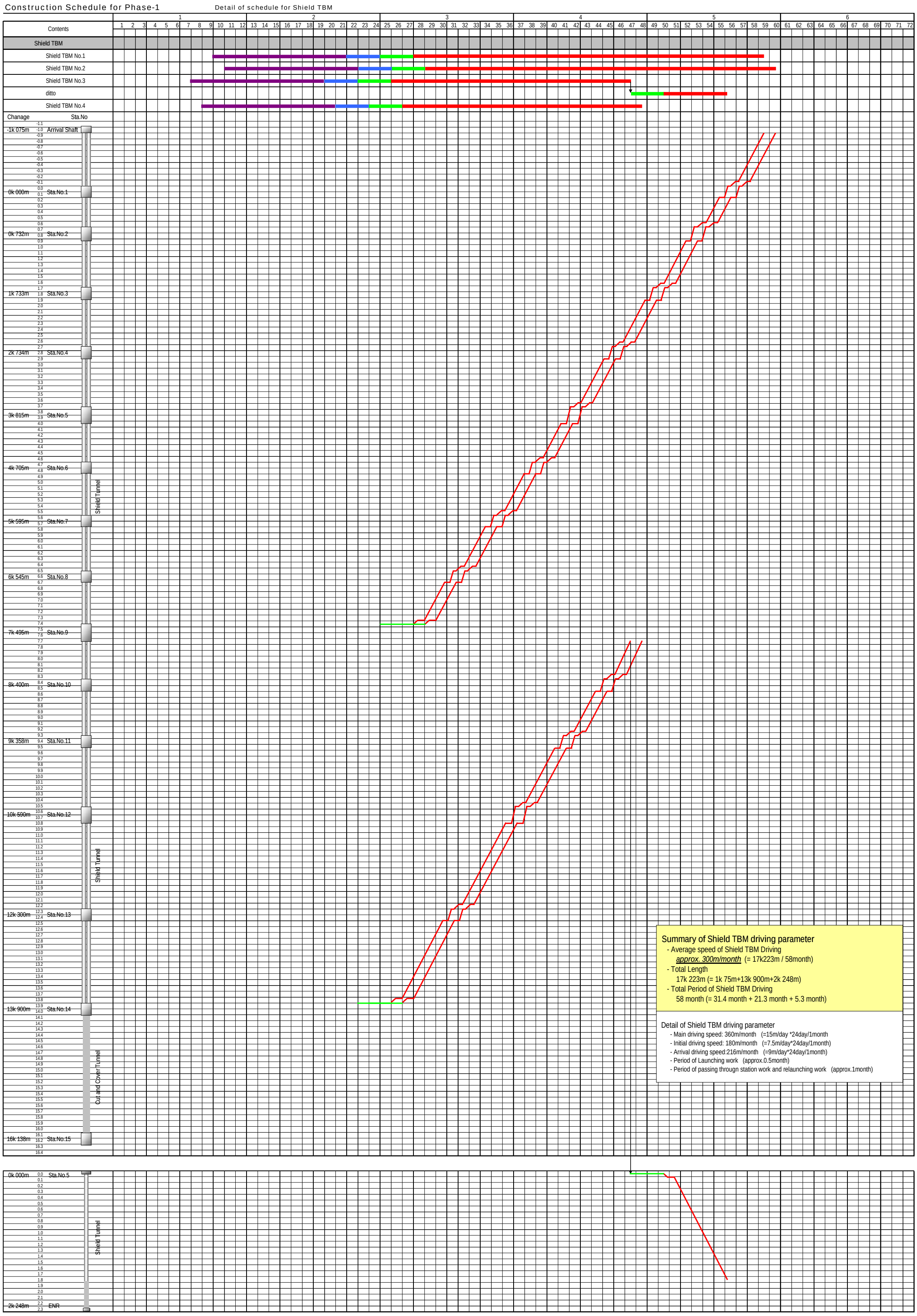


Source: JICA Study Team

Figure 4-264 Construction Plan of Shield Tunnel

c) Schedule of Shield Tunneling

Construction schedule chart for shield tunneling considering above conditions is shown in Figure 4-265.



Source: JICA Study Team

Figure 4-265 Detailed Schedule of Shield TBM Driving

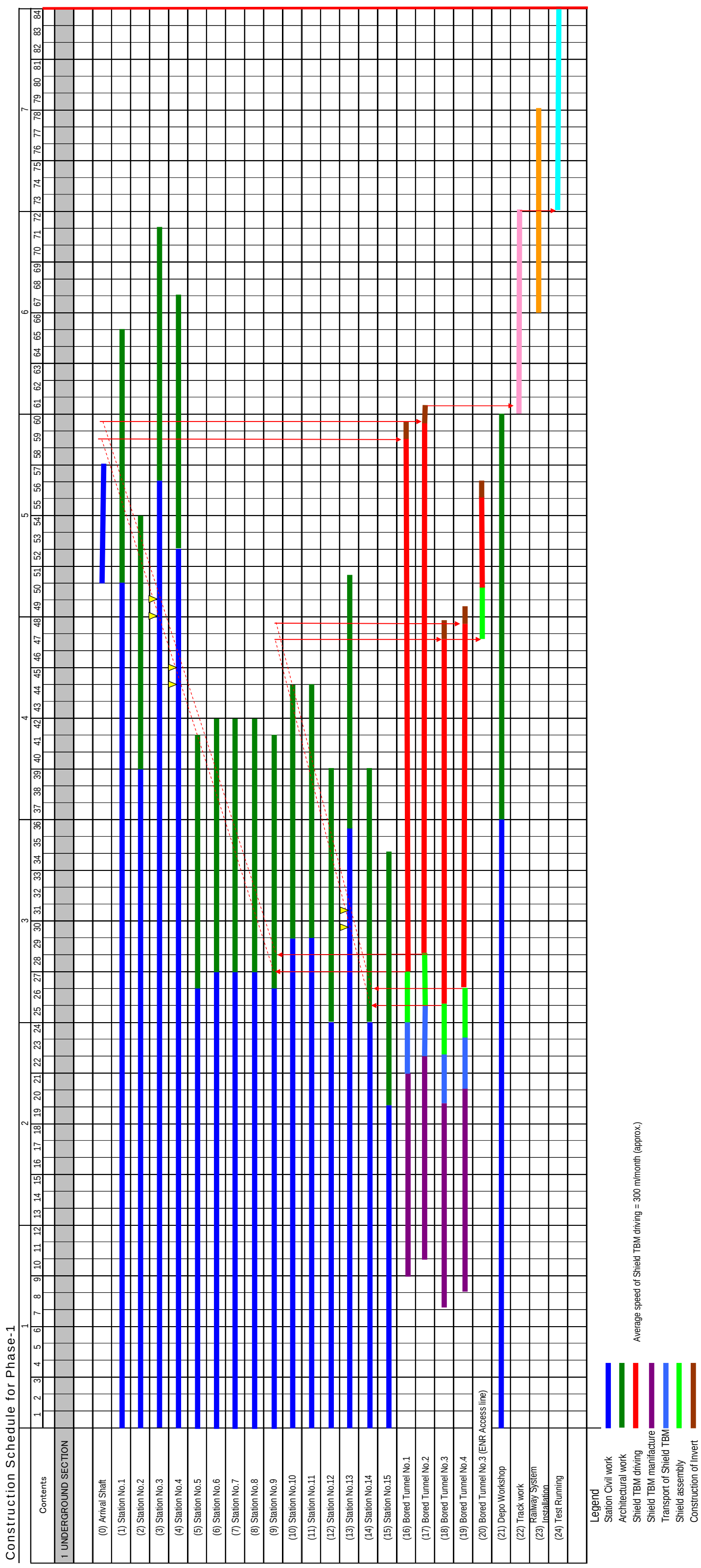
(4) Construction Schedule

Considering above conditions and related works such as track work etc, construction schedule is shown Figure 4-266.

Regarding the number of shield TBM in case two sets are used, the construction period is estimated to be approximately nine years as shown in Figure 4-267. As the length of Metro Line 4 Phase 1 exceeds 16 km, the use of two TBM sets will be unrealistic and not suitable. Therefore, the use of four sets of shield TBMs is recommended.

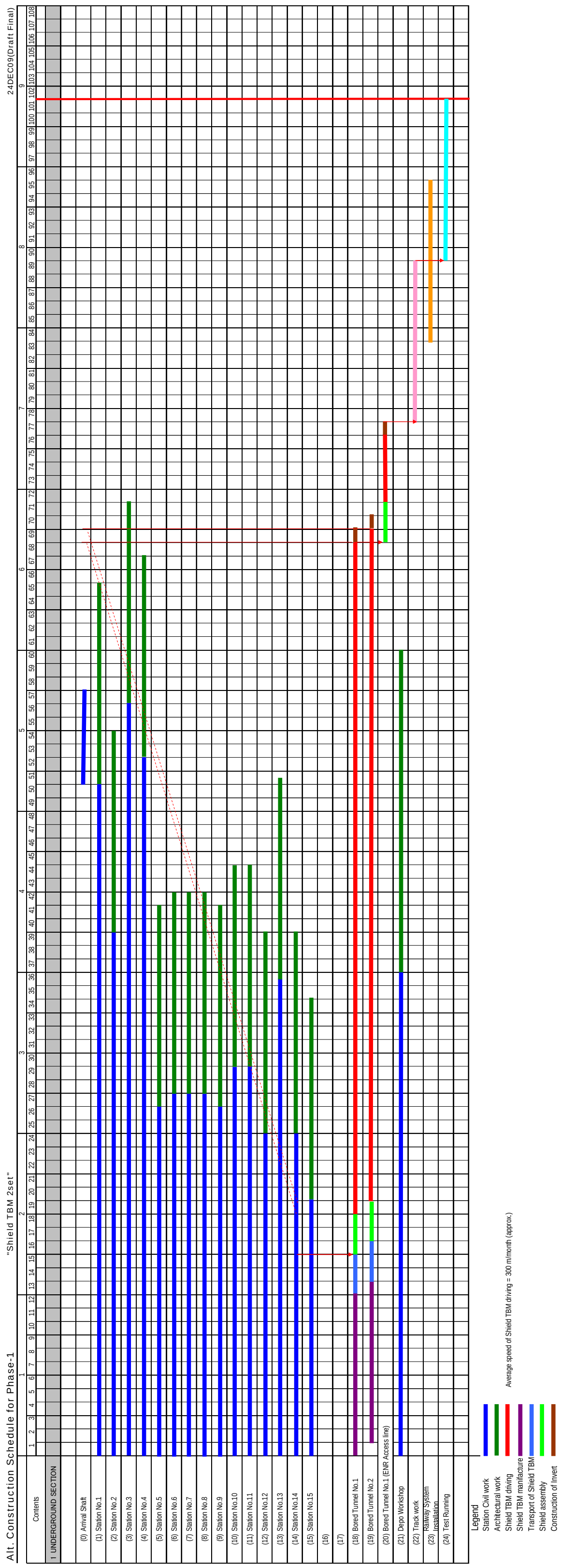
Table 4-77 Construction Schedule

	Period of Construction	Number of Shield TBM
Base Case	Approximately 7 years	4 sets
Alternative Case	Approximately 9 years	2 sets



Source: JICA Study Team

Figure 4-266 Construction Schedule



Source: JICA Study Team

Figure 4-267 Construction Schedule (Alternative)

4.8 Civil Works (Track)

4.8.1 Specifications of Existing Lines

Track specifications for existing lines and recommended track specification for Metro Line 4 are shown in Table 4-78 and Table 4-79, respectively.

Table 4-78 Track Specifications of Existing Lines

	Metro Line 1	Metro Line 2	Metro Line 3
Gauge	1,435 mm	1,435 mm	1,435 mm
Rail	UIC54	UIC54	UIC54
Sleeper	PSC	PSC, twin-block	PSC, twin-block
Type of track	Ballast	Tunnel: twin-block embedded in concrete Viaduct: ballast	-
Continuous welded rail	Adopted	Adopted	-

* PSC means "Pre-stressed concrete".
Source: JICA Study Team

Table 4-79 Proposed Track Equipments Specifications for Metro Line 4

	Metro Line 4
Gauge	1,435 mm (standard gauge)
Rail	UIC54 (general section) THH340 (for steep curve section - under R400 m)
Sleeper	PSC with anti-vibration rubber (for tunnel section) PSC (for workshop/depot) Synthetic (for turnout)
Type of track	Resiliently supported track (for tunnel section) Ballasted track (for viaduct section & workshop/depot)
Continuous welded rail	Recommended

Source: JICA Study Team

(1) Gauge

The recommended gauge is 1,435 mm, for the following reasons:

- Compatibility with existing metro lines and ENR lines.
- Inter-operability in case of emergency.
- Possibility of sharing track machines.
- Possibility of transporting new cars by rail through ENR lines.

(2) Rail

The recommended rail is either UIC54 or UIC60. Each type is suitable for Metro Line 4.

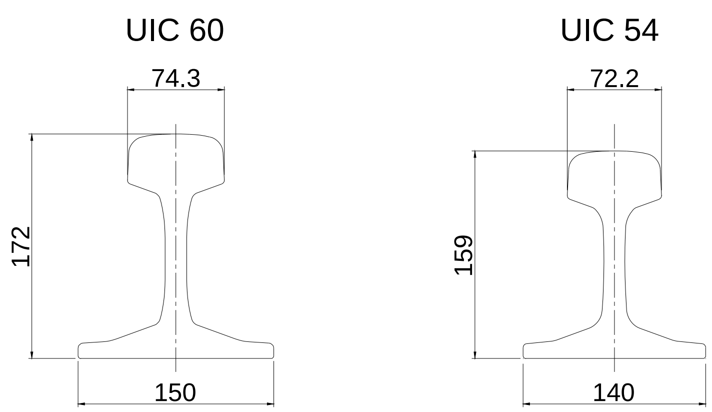
The advantages of UIC54 rails are as follows:

- Can totally control rail stock among the metro lines.
- Can save on cost as result from package purchase of rails for all metro lines.
- Metro line is only for passenger use and the new car body weight will become light. UIC54 rail performs adequately under this condition.

On the other hand, UIC60 rail has the following advantages;

Annual gross tonnage for Metro Line 4 will be over 40 million tonnes already after three years of starting operation (Refer the Table 4-80). Thus, it is also reasonable to adopt UIC60 rail to save on maintenance frequency and its cost.

Moreover, heavy rails have the ability to reduce vibration caused by the running train.



Source: JICA Study Team

Figure 4-268 Shape of the UIC Rails

Table 4-80 Annual Gross Tonnage

		2020	2023	2027	2050
Train Frequency	Working day	198	343	353	367
	Holiday	127	223	233	240
Max. capacity/train		2000	2000	2000	2000
		Annual gross tonnage (ton)			
Ave. ridership	40 %	21,495,000	37,329,000	38,526,000	39,984,000
	50 %	22,281,000	38,694,000	39,935,000	41,447,000
	60 %	23,067,000	40,060,000	41,345,000	42,910,000
	70 %	23,854,000	41,426,000	42,754,000	44,373,000
	80 %	24,640,000	42,791,000	44,164,000	45,835,000
Ave. daily tonnage		63,000	110,000	113,000	118,000

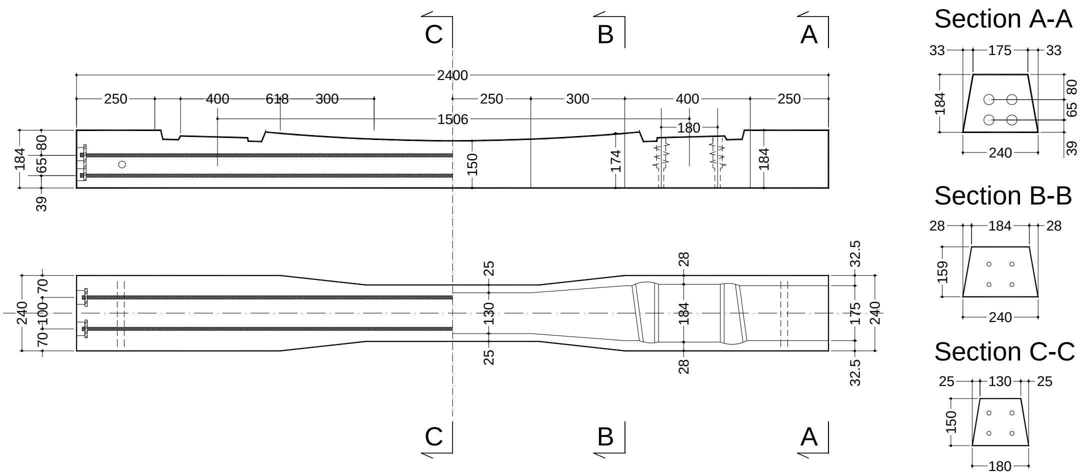
Source: JICA Study Team

Furthermore, installing a head-hardened rail in the steep curve section is recommended to reduce labour and maintenance costs.

At this stage, the JICA Study Team recommends UIC54, although it is necessary to take overall considerations for selecting the type of rail. Therefore, JICA Study Team will carry out further study in detail and discuss more, considering the comprehensive conditions during the basic design stage.

(3) Sleepers

The recommended sleeper is the pre-stressed concrete type for the entire system, except for turnout sections. One example of PSC sleeper is shown below:



Source: JICA Study Team

Figure 4-269 Sample of PSC Sleeper

Especially in the turnout section, synthetic-type sleeper is recommended. One of the synthetic sleepers, which consists of glass-fibre and urethane foam, has been developed in Japan. These are mainly used in turnouts and steel bridge sections, instead of timber sleepers. Furthermore, these sleepers have been used for more than 25 years on the track for the bullet train.

Generally, synthetic sleepers have the following advantages:

- Reduced labour in track-laying because of their light weight (similar to wood).
- Long life-time (same length as PSC sleepers).
- Flexible for various machining works
- Having performance of Waterproof
- Easy process for drilling and nailing
- Have electrical insulation

Source: JICA Study Team

Figure 4-270 Synthetic Sleeper

The physical properties are as shown below. These are not design values but rather standard values.

Table 4-81 Basic Physical Properties and Secular Change

Item	Unit	Synthetic sleeper (Grade1)		
		New	After 10 years	After 15 years
Specific gravity	-	0.74	0.74	0.74
Bending strength	MPa	142	125	131
Young's modulus of bending elasticity	MPa	8100	8000	8160
Vertical compressive strength	MPa	58	66	63
Shear strength	MPa	10	9.5	9.6
Hardness	MPa	28	25	17

Source: Japanese manufacturer's report

(4) Types of Track

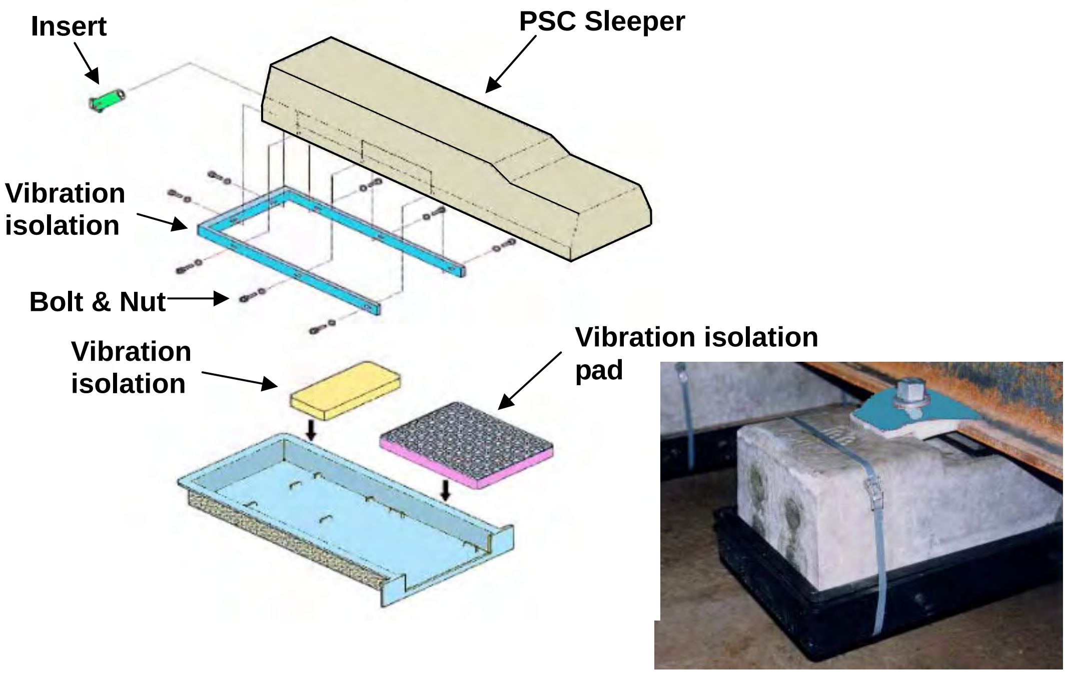
Recommended type of track is the resiliently-supported track. It is one of the solid-bed tracks, which consist of removable sleepers with resilient rubber pads, as shown below.

Source: JICA Study Team

Figure 4-271 Resiliently-Supported Track

The characteristics of resiliently-supported tracks are as follows:

- Has anti-vibration and noise reduction
- Easy to replace sleeper and resilient rubber pads when elastic fatigue occurs.
- Reduce the load for rail and fastening equipments
- Low maintenance cycle and cost



Source: JICA Study Team

Figure 4-272 Example of Anti-vibration System

For reference, a comparison of ballasted track and solid-bed track is shown in Table 4-82.

Table 4-82 Characteristics of General Tracks

	Ballasted Track	Solid-bed Track
Advantage	Reasonable construction cost It is possible to follow a subsidence of structure Having anti-vibration performance	Can save maintenance cost Less distortion
Disadvantage	Need high maintenance at frequent intervals, involving replacement and tamping of ballast Having a significant risk of electrolytic corrosion at the underground section.	Need higher initial cost than the ballasted track Having more vibration than the ballasted track

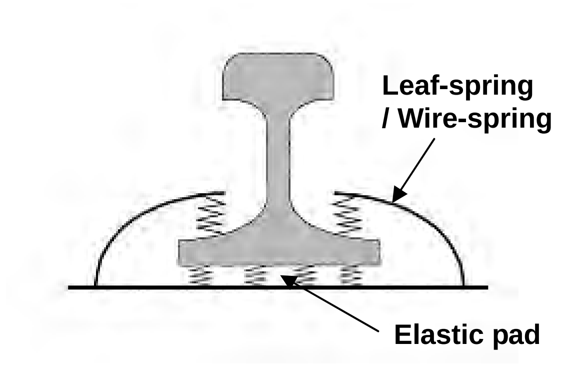
Source: JICA Study Team

The preceding table does not make clear the obvious advantage but only the result of the comparison. The basic policy therefore depends on the what the operation company deems most important. In this study, all the sections of Phase 1 are underground. Thus, it is difficult to maintain the track rather than doing it an open section. Initial cost is not much different between ballasted track and solid-bed track in case of a tunnel section. In general, however, solid-bed track has an advantage. Furthermore, Metro Line 4 will be required to reduce noise and vibration caused by the friction between wheels and rail, and the oscillation of the vehicle. Therefore, the resiliently supported track, as one type of solid-bed type tracks, is recommended.

(5) Fastenings

A fastening device is also good for the type of elastic fastening to maximize the ability of the synthetic supported track.

Double elastic fastening is recommended for the section of the mainline. It consists of leaf-spring and wire-spring fastening a rail and elastic pad seating under the base of the rail. Recently, it is adopted in urban and high-speed railways all over the world.

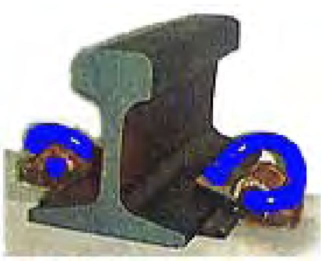


Source: JICA Study Team

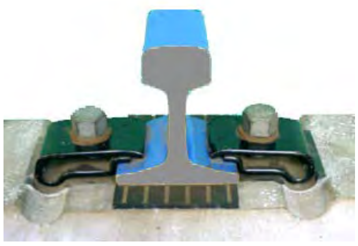
Figure 4-273 Concept of Double Elastic Fastening

Advantages of the double elastic fastening are:

- It is able to reduce impact occurring between rail and sleeper because of fastening is always pushing the rail face with the uniform force following the bend of the rail.
- Elastic pad is has cushioning and damping effects, which can prolong the life of track equipments.
- It does not require anti-creepers. Rail and sleeper are always fastened by the effect of the spring, sufficiently resisting the force of rail creep by the friction. In case of using it at a solid-bed track, it is able to control easily the force of rail creep by adjusting the force of fastening.
- Some types of fastening have the effect of transverse springs, which are able to disperse lateral force. As a result, it is able to save maintenance and labour because by alleviating the overload for sleepers and preventing irregularity of the line.


Pandrol (wire-spring)

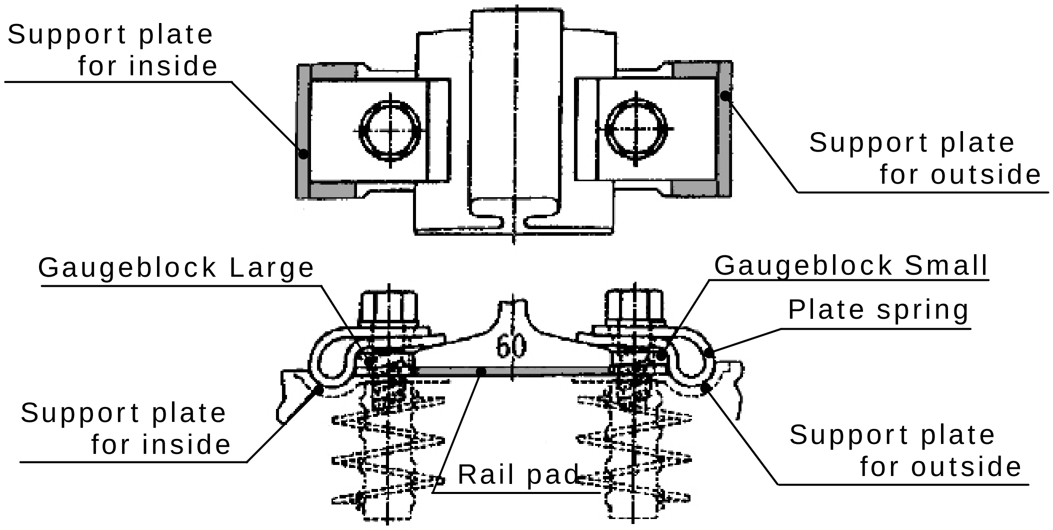

NABLA (leaf-spring)


Type-9 in JAPAN (leaf-spring)

Source: JICA Study Team

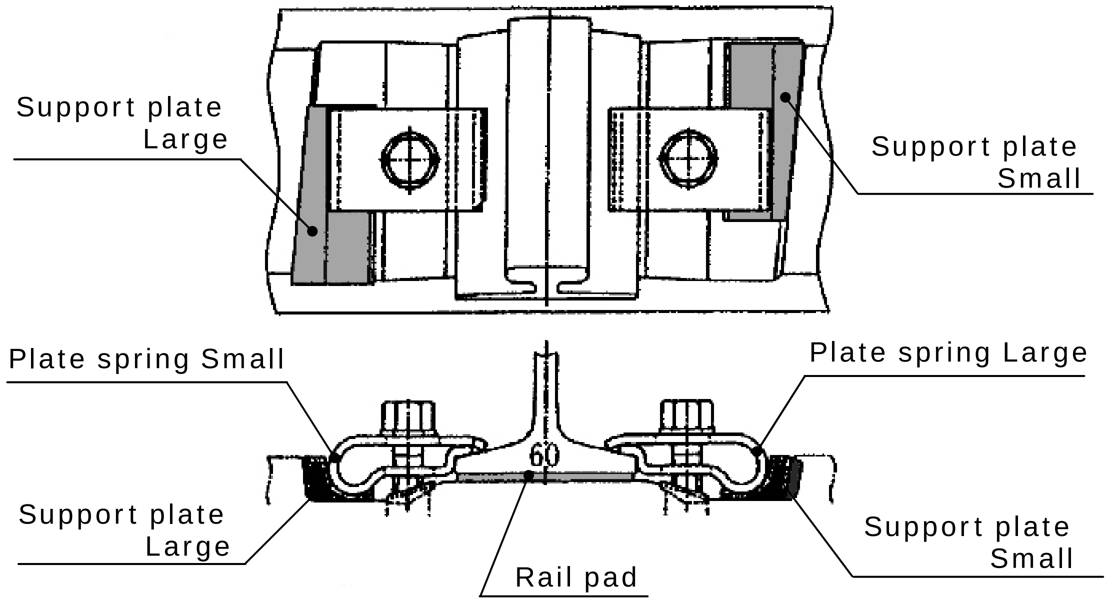
Figure 4-274 Typical Types of Fastening System

An example of double elastic fastening in Japan is shown in Figure 4-275 and Figure 4-276.



Source: JICA Study Team

Figure 4-275 Double Elastic Fastening for Straight and over 800 m Radius Curve Section



Source: JICA Study Team

Figure 4-276 Double Elastic Fastening for under 800 m Radius Curve Section